

# *The* **CRUSHED STONE JOURNAL**

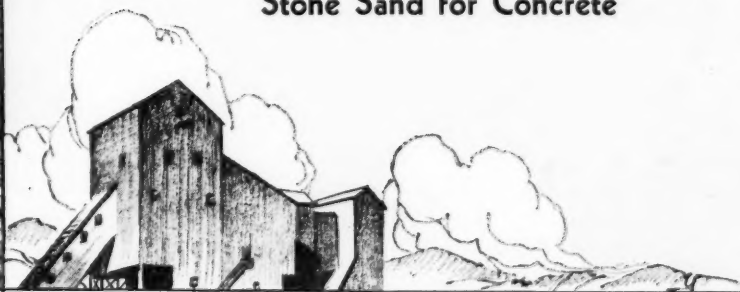
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**May-June • 1932**

Official Publication  
**NATIONAL CRUSHED STONE ASSOCIATION**



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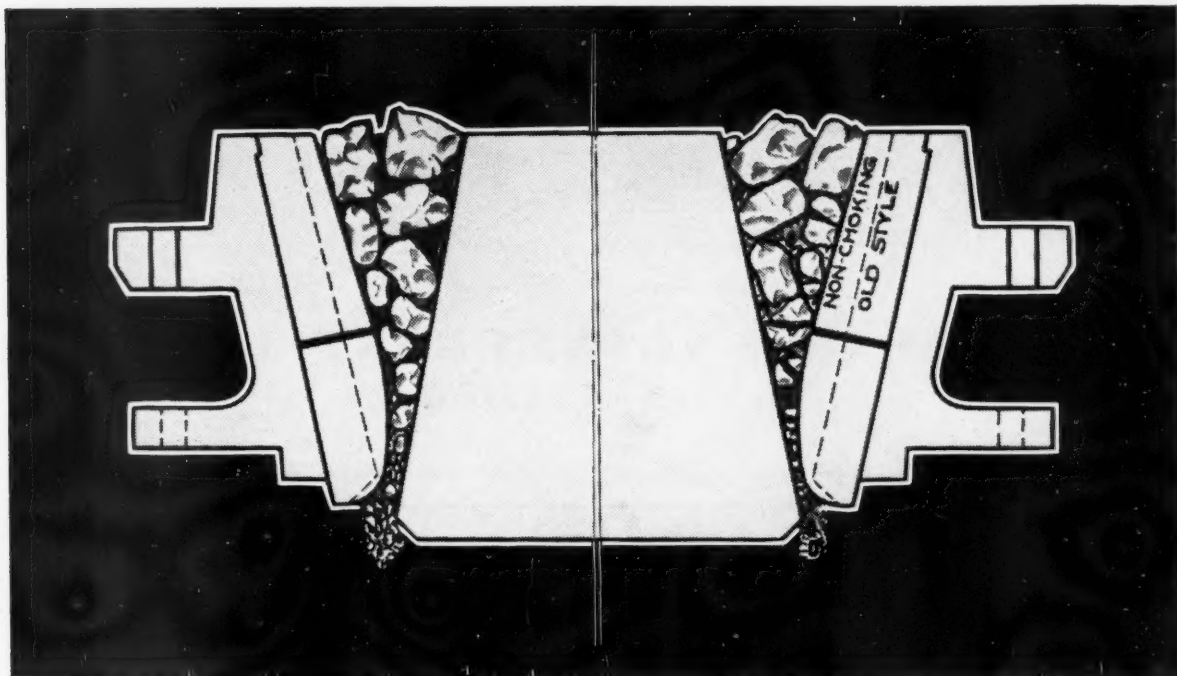
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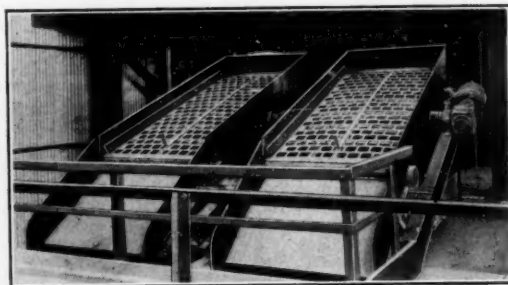
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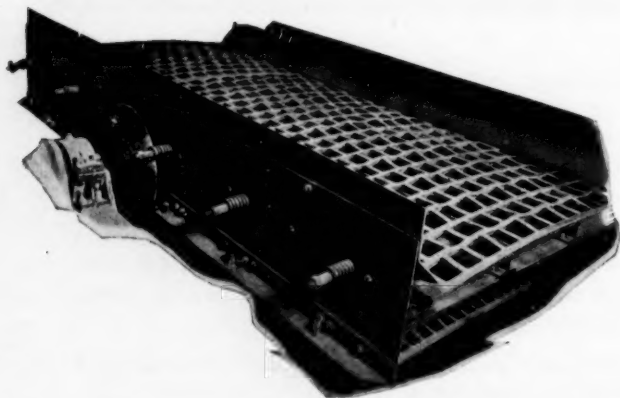
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Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

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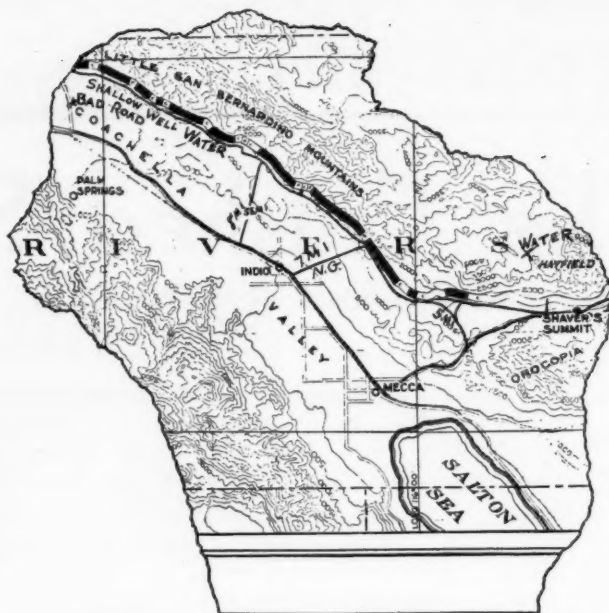
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# THE CRUSHED STONE JOURNAL

WASHINGTON, D. C.

Vol. VIII No. 4

MAY-JUNE, 1932

## The National Crushed Stone Association Circular Testing Track

By A. T. GOLDBECK<sup>1</sup>  
J. E. GRAY<sup>2</sup>  
L. L. LUDLOW, JR.<sup>3</sup>

IT IS interesting to look back over the past ten years of highway construction and highway traffic. At the beginning of this period we were concerned with the building up of a main system of highways upon which might operate the heaviest kinds of motor vehicles equipped with solid rubber tires. In the meantime traffic has changed and we have seen a surprising development in the efficiency of pneumatic tires and in the design of motor vehicles. Correspondingly, we have seen the main highway systems grow amazingly, some of them practically to completion. Our heavy trucks now are carried, not merely on pneumatic tires, but on balloon tires, and in many cases heavy gross loads are distributed on more than four wheels so that the wheel load is much reduced.

This change in the design of the heavy motor truck and in the almost universal use of pneumatic tires to carry heavy wheel loads, undoubtedly has presented new problems to the highway engineer. These developments have led to great economies in highway construction and maintenance and coming over the horizon we see a still newer development resulting from the design of the so-called air wheel, such as used on airplanes, a development which permits of the use of tires having only 10 pounds of air pressure. Who can predict what new problems in economics this new tire will put before highway engineers for solution and who can predict what effect it will have on the crushed stone industry?

The partial completion of our main highway systems has turned the attention of highway engineers to the secondary systems more actively than ever before and these improvements in vehicle and tire design have

♦ The research laboratory of the National Crushed Stone Association is constantly engaged in developing information of interest and value to crushed stone producers. In pursuing such research investigational work it frequently becomes necessary to develop special laboratory apparatus. The newest addition to such equipment is our "circular track." In the following article is given description of the apparatus and many of the problems regarding which information will be sought.

made possible lighter types of roads for the secondary highways, at least until the traffic on them develops to a greater extent. All kinds of light surfaces are being used, involving, in most cases, the use of bituminous binding materials and these surfaces take the form either of traffic bound construction, mixed-in-place bituminous pavements, pre-mixed bituminous surfaces, or bituminous surface treatments with coarse aggregate cover material.

In view of the growing importance of bituminous surfaces and especially those involving surface treatments and the more or less open types of mixtures, it was thought highly desirable that the National Crushed Stone Association engage in research to solve some of the problems in these types of roads in which crushed stone is a most important ingredient. Naturally, it is the desire of the crushed stone producer that his material be used in the best possible way so as to give the most efficient service. The most favorable gradation for one type of stone may not be the most favorable for another type.

A number of questions occur, an answer to which would be useful to the highway engineer and to the crushed stone producer as well. Typical of such questions are the following:

1. What is the most favorable gradation for crushed stone for use in different thicknesses of mixed-in-place construction?
2. How does the stability of crushed stone aggregate

<sup>1</sup> Director, Bureau of Engineering, National Crushed Stone Association.

<sup>2</sup> Laboratory Engineer, National Crushed Stone Association.

<sup>3</sup> Assistant Laboratory Engineer, National Crushed Stone Association.

- for mixed-in-place construction compare with other aggregates?
3. What is the proper percentage of bitumen to use in different types of mixed-in-place construction with different kinds of aggregates?
  4. What is the most favorable gradation for use in pre-mixed, cold lay bituminous concretes?
  5. Cannot stone sand be used to good advantage in sheet asphalt construction in place of natural sand?
  6. What is the effect of quality and characteristics of aggregate in macadam bases on the degree of support offered to bituminous surfaces?
  7. If screenings are desirable for use as a blanket layer over a clay subgrade under macadam road construction, what is the most favorable thickness of blanket layer to use?

Numerous other questions, if answered properly, should be highly beneficial to producer and engineer as well in connection with the growing trend in low cost road construction.

To answer questions of this nature, a type of research has been started in the laboratories of the National Crushed Stone Association which is somewhat unique for it involves the use of a circular track testing apparatus upon which may be operated wheel loads like those on our highways.

The Research Advisory Committee of the Associa-

tion after carefully studying the various problems with which the industry is confronted, decided that it would be best to conduct investigations on low cost roads in the laboratory, making use of a circular track apparatus which had been suggested to them as the most promising piece of equipment for this purpose. The idea is to first obtain laboratory results and then to supplement these with field observations and with the results of investigations conducted elsewhere. It is the purpose of the present article to describe in a little detail the apparatus which was designed by the authors and in part constructed by two of them.

In a general way the apparatus consists of a circular track 14 feet in mean diameter upon which may be operated the desired traffic. The size of the track was limited by the space available for its construction. The base is made of reinforced concrete 6 inches in thickness and with an overall width of 2 feet 2 inches, including side curbs 4 inches in width and 6 inches in height. The runway upon which various types of surfaces may be constructed is 18 inches in width and these test surfaces may be built to a maximum thickness of 6 inches. The circular concrete base is anchored in place by means of dowels set in holes in the concrete floor of the laboratory. These holes were filled with bituminous cement before placing the dowels. This permits the reinforced concrete circular base to expand comparatively freely as changes in temperature occur. In view of the fact that it is necessary to maintain the bituminous test surface at a constant temperature, means were provided for heating the track.

Before laying the concrete base a one-inch layer of

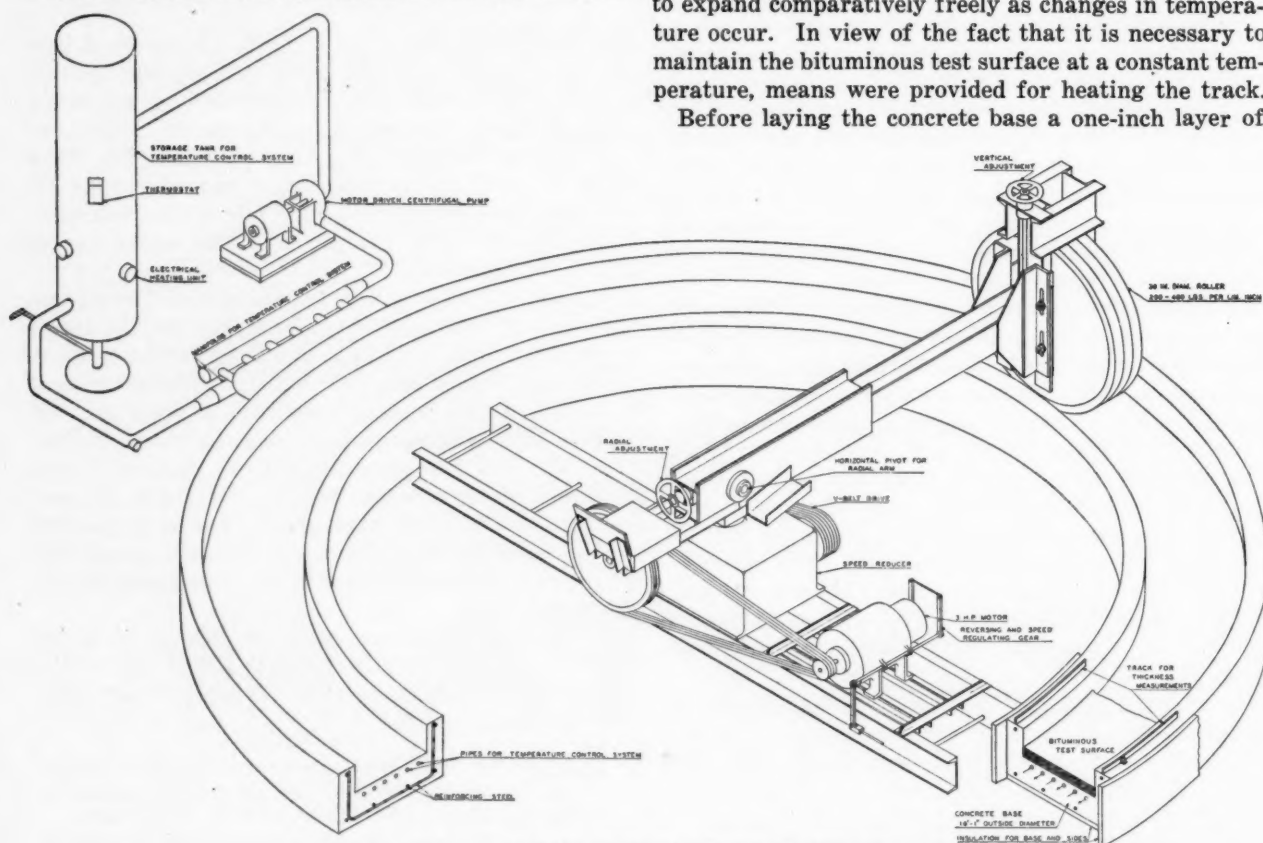


Figure 1.—Isometric View of Circular Track Testing Apparatus

celotex was placed on the floor and the concrete laid on this insulating material. The celotex serves not only as an insulator but also as a cushion. This seems desirable because the track is constructed on the sec-

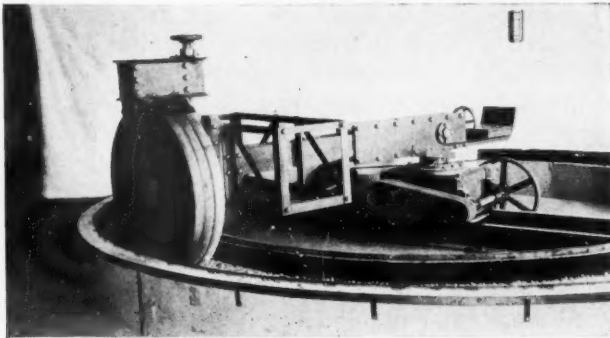


Figure 2

ond floor of our laboratory building and it is necessary to reduce impact and vibration to a minimum. Much thought was given to the method to be adopted for keeping the bituminous test surfaces at a constant temperature and the scheme finally evolved consists of a system of water pipes installed in the concrete base, approximately  $3/4$  of an inch from the surface of the base. Six  $3/4$ -inch pipes are used for this purpose. They are bent to conform with the shape of the track and are spaced equally across the 18 inch width upon which the test sections are laid. Warm water is circulated through these pipes by means of an electrically driven centrifugal pump. The water is heated by the use of electrical heating units placed in the tank to which the pipes are connected and also by an additional unit placed in the pipe system.

Consideration was given to the question of keeping the temperature constant throughout the circumference of the track and to accomplish this purpose the water in three of the pipes circulates in a clockwise direction and in the remaining three pipes in a counterclockwise direction. The pipes in one system alternate with those in the other. An electrical thermostat is also provided to keep the water at any desired temperature. It is possible by means of this system to maintain the track at a temperature of  $140^{\circ}\text{F}$ . if desired. It would also be possible with proper refrigerating apparatus to cool the test sections to a comparatively low temperature, thus simulating winter conditions. In addition, the track may be flooded with water so as to study the effect of continuous moisture.

Celotex insulation is provided around the sides of the concrete base and thus most of the heat is retained and the apparatus is operated economically.

In studying the proper design for the load applying mechanism, thought was given to the action of traffic on the highways. Motor vehicles, of necessity, have at least one set of driving wheels which exert tractive

effort on the road surface. The steering wheels do not exert tractive effort but merely roll on the surface. It has been observed, however, that whenever a bituminous pavement moves or shoves under the action of traffic, it invariably moves in the direction of the traffic. The tractive effort exerted by the rear wheels of a motor vehicle must be toward the rear in order that the vehicle may move forward and the natural inference would be that the pavement would therefore shove toward the rear instead of forward. The tractive effort, however, is not the only force exerted on the pavement surface, for there is a rolling action of both the front and the rear wheels which tends to make the pavement surface move forward and evidently this rolling effect is more severe than the backward acting tractive effort. When the brakes are applied on a down grade, the retardation of the vehicle produces on the pavement a forward-acting force, the effect of which must be added to the rolling action and it has often been observed that the very worst shoving or movement of the bituminous pavement takes place under such conditions. In view of these opposite effects of tractive effort and rolling action, it was decided that a more accelerative effect would be obtained in our testing apparatus by the use of a machine which exerted no tractive effort on the test section, but rather merely the rolling effect. In view of this consideration and also because of the simpler driving mechanism required, the apparatus finally evolved consists of a wheel mounted at the end of a radial arm which is driven by power applied through a vertical rotating axle at the center of the track.

The machine is illustrated in the isometric view shown in Fig. 1 and also in the accompanying photographs, Figures 2 and 3. Power is provided by the use of a 3 H.P. reversible, variable speed, electric motor. The variations in speed and reversibility are accomplished through a hand-operated mechanism for shifting the brushes of the motor. Mounted at the center

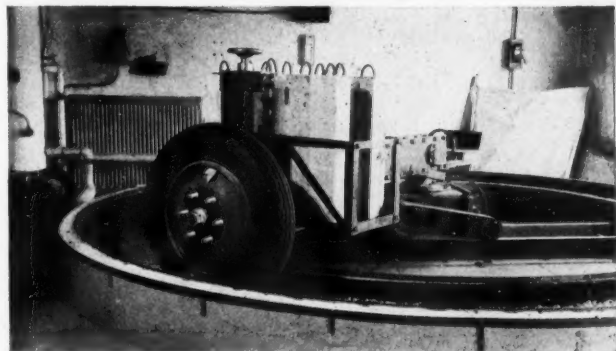


Figure 3

of the track is a vertical speed reducer having a ratio of 50 to 1. V-belt drives are used through a countershaft so that further reduction in speed is obtained. Variations in amount of speed reduction may be ob-

tained readily through the use of different sizes of pulleys in the V-belt driving mechanism. This makes for great flexibility in the speed at which the testing machine may be operated.

In designing the testing device it was thought desirable to provide means for rolling the test sections in practically the same manner as they would be rolled in actual road construction and the machine as finally built has a roller 3 feet in diameter and 6 inches wide composed of 3 segments, each 2 inches in width and operating independently of one another. This roller is mounted on an axle fastened to a yoke which in turn is mounted at the end of the radial arm. The inner end of this arm is attached to the vertical axis of the speed reducing mechanism. Three segments were used in the roller to prevent any dragging over the surface, due to the difference in length of path traveled by the inner and outer edges of the roller. The level of the radial arm may be adjusted so that the roller will be kept in a vertical position irrespective of the thickness of the test section. This is accomplished by the use of a hand-wheel operated, long bolt which serves as an elevating device. The radial arm is made up in two sections, the outermost of which may be slid with respect to the other. This arm may be extended in length so that the path of the roller may be changed at will and thus the entire width of the track may be rolled to the desired amount.

This roller may be used not merely to compact the surface but also as a portion of the testing apparatus if so desired; also, in place of the roller a pneumatic tired wheel may be used as shown in the accompanying photograph. The wheel is an actual motor truck wheel upon which is mounted a 7.00—20 pneumatic tire, 34 inches in overall diameter and carrying an air pressure of 55 pounds per square inch. When the pneumatic tired wheel is used, it is loaded up to its maximum capacity of 1900 pounds. This is accomplished

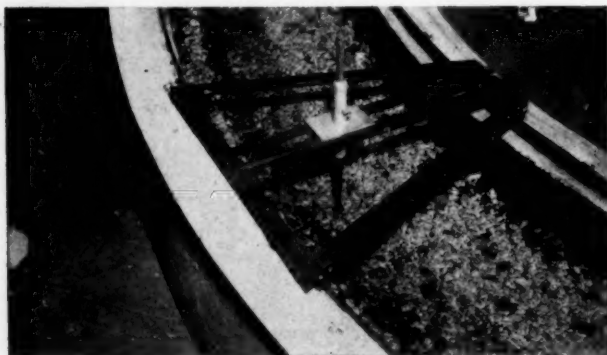


Figure 4.—Depth Gage for Measuring the Stability or Compaction of a Bituminous Surface

by the use of heavy weights of concrete made up with iron slugs as the coarse aggregate. A differential hoist mounted on a stiff legged crane is employed for handling these weights. It also is used for dismounting the

roller and mounting the pneumatic tired wheel on the apparatus and vice versa. This change may easily be effected in 30 minutes.

At the present time the machine is operated at a speed of 3 miles per hour but this may be increased up to approximately 12 miles per hour with safety, for the design has taken into account the centrifugal forces which may come into play at higher speeds.

Although this circular track apparatus was not placed in operation until approximately February first of this year, tests results of value have already been obtained. The possibilities of such a testing machine for obtaining quick and accurate information on a number of problems in which road engineers and crushed stone producers are interested should immediately be evident. It places in our hands a testing machine especially designed for low cost road investigations and with its use we can predetermine the results to be expected from service behavior. Furthermore, tests may be made quickly because we can simulate a very high intensity of traffic.

For measuring the stability of a bituminous surface or for measuring the compaction of that surface, a form of depth gage has been devised which is illustrated in Fig. 4. Tracks made of  $\frac{1}{8}$ " by 1" strap iron are mounted on the tops of the concrete curbs and a small bridge made up of structural shapes slides on this steel track. Fastened to this bridge is a horizontal graduated scale and a slide carrying an adjustable graduated vertical rod is mounted so that it may be moved laterally across the track. By reading the lateral measurements and also the depth measurements on the vertical rod, the exact level and location of any particular point on the track is determined when the bridge is set in a definite position. This furnishes a rapid and accurate means for detecting any movement which has taken place in the track during its operation. Thus far, investigations have been conducted on the stability of various gradations of crushed stone and other aggregates, using gradations which are normally used for mixed-in-place construction. Tests have also been conducted on several different kinds of cover materials for use in surface treatment and it is planned shortly to make additional investigations having to do with the stability of mixed-in-place construction as influenced by gradation and type of aggregate.

The possibilities of such a testing device must be evident to the highway engineer and to the crushed stone industry. With its use results may be obtained in the laboratory which would require a considerable length of time to obtain in any other way. Furthermore, the fact that the laboratory test is under definite temperature control and under definite conditions of subgrade moisture and traffic should make the results reliable and comparable. Such uniformity of control is practically impossible in the field.

## Bradford D. Pierce, Jr.

**F**ATE has dealt us an unkind blow. He who controls our destinies has turned another page in the history of our industry with a finality that knows no recourse—Bradford D. Pierce, Jr., is dead.

To the many in our industry who enjoyed his acquaintance, his death will mark the passing of a pioneer, but to that small group of enthusiastic and farsighted men who many years ago first visioned a national organization of crushed stone producers, announcement of the death of Brad Pierce will be received with a poignant, heart-felt grief, for he was an enthusiastic and inspiring member of that indomitable band—the founders of the National Crushed Stone Association. The men who knew him intimately and long will feel a sense of irreparable loss and will be saddened to know that they will henceforth be denied the warmth of his friendship and inspiring personality.

Mr. Pierce died at his home in Bridgeport, Connecticut, on Monday morning, April 18, 1932, after an illness of about four months resulting from a heart attack. The funeral was held at his home on Wednesday afternoon with the Reverend William Horace Day of the United Congregational Church officiating. Burial took place in the family plot at the Mountain Grove Cemetery. He is survived by his widow, Julia DeForest Pierce, two daughters, Marjorie DeForest Merwin and Alice Bart-ram Grout, and several grandchildren.

Mr. Pierce was born in Bridgeport on December 26, 1865. His father, Bradford D. Pierce, Sr., was one of the pioneers of this country in building light macadam roads. Benefiting from the experience gained with his father, he organized the B. D. Pierce, Jr., Company, which was among the pioneer road builders of Connecticut. In the late 1890's he opened one of the early quarries in New England at Bridgeport, furnishing material for street construction in that municipality. About 1900 Mr. Pierce purchased a trap rock quarry and crushing plant at Reeds Gap, Middlefield, Connecticut, which had been operated in a small way by the Byxbee DePeyster Company. This plant was enlarged and a contract secured to supply the New York, New Haven and Hartford Railroad Company with ballast for the Shore Line Division between New Haven and New London.



B. D. PIERCE, JR.  
1865 - 1932

In 1902, largely through Mr. Pierce's efforts, a number of trap rock producers in Connecticut were brought together and merged their holdings to form the Connecticut Trap Rock Co., Inc. Mr. Pierce became the first president of this company and served in that capacity until 1925, at which time, desiring to retire from the crushed stone business, he sold the entire property to The Connecticut Quarries Co., Inc. Upon retiring from the crushed stone industry, Mr. Pierce

formed the B. D. Pierce, Jr., Company, with offices in Bridgeport, to engage in general insurance. Until his death he was president of this company as well as of a subsidiary, The Investors Mortgage and Guaranty Company.

Mr. Pierce took an active and leading part in the civic affairs and social welfare work of his city. During the period of the World War he was at the head of two campaigns for the Red Cross which raised a total of more than a million and a quarter dollars. During this same period he was for two years president of the Bridgeport Chamber of Commerce, and when the mineral aggregates section of the War Industries Board was formed, Mr. Pierce was made chairman of the New England Section which included all of the stone,

sand and gravel producers in that territory. For thirteen years he served as a member of the Board of Apportionment and Taxation of the City of Bridgeport and was also a member of the Executive Committee of the group for raising funds for charitable and relief organizations in the city, which developed into the Community Chest. Mr. Pierce was prominently identified with a number of fraternal organizations. He was a Thirty-second Degree Mason, a member of the Commandary and of Pyramid Temple, Nobles of the Mystic Shrine. He was also a member of the Society of Colonial Wars of the State of Connecticut.

As he faced the inevitable he should have been happy in the knowledge that Christ was speaking to such as he when He said, "Well done, thou good and faithful servant." With sad and grieving hearts we record his passing to the land from which no traveler returns—his accomplishments will remain a lasting tribute to his memory; his lovable personality and farsighted vision have etched in letters which time cannot efface—Our Friend and Counsellor, Brad Pierce.

# Dolomite Sand in Concrete For the Henley Street Bridge, Knoxville, Tennessee<sup>1</sup>

By L. M. DOW

Supervising Engineer, Knoxville, Tenn.

**T**HE Henley Bridge is a million-dollar reinforced concrete spandrel arch structure over the Tennessee River at Knoxville. This beautiful bridge, recently completed, forms the first link in the great broad highway proposed from Knoxville to the Smoky Mountain National Park.

A brief history of the bridge takes in several controversies and dates back to 1928, at which time the City and County voted \$1,500,000 to do the work. Immediately thereafter the steel and cement interests got busy and there was a fight on between concrete and steel, with the concrete finally winning out. The concrete design was given to the Greiner Engineering Company of Baltimore.

The next fight came over the width of the roadway. The City Planning Commission, an advisory board, had recommended a 54-foot bridge, giving six traffic lanes, but the designers contended there was not enough money for a bridge of this width; therefore, the city officials concurred with them and agreed to accept a 36-foot bridge. Plans were completed on this basis and the city was ready to ask for bids. Then it became generally known that only a 36-foot roadway had been provided for. The public, backed by the newspapers, became aroused and demanded a wider bridge. This caused the City Council to throw the whole bridge question open again and other engineering firms were invited to participate and to furnish new tentative plans. Several of the engineering companies practically guaranteed a 54-foot bridge for around \$1,000,000. As a result, the Greiner plans were paid for and "pigeon holed." New plans by the Marsh Engineering Company of Des Moines, Iowa, were adopted, provision being made by the city that the supervision could be let separate. The supervision contract brought on another fight in the Council and this work was finally awarded to my office. The contract for the construction was let to Booth & Flinn Company of Pittsburgh.

Work began on September 20, 1930, and soon afterwards the contractors sub-let the concrete to the Ready-Mixed Concrete Company of Knoxville. They proposed to mix all the concrete at their central mixing plant, located about three miles from the bridge site, and to haul the ready mixed concrete in their thirteen Blaw Knox Agitator trucks. They also proposed to use products of the American Limestone Company for

♦ Among other important subjects discussed at the convention last January was included "Stone Sand." There has been comparatively little definite information on this phase of our industry and consequently the two following papers by prominent engineers should prove of exceptional value. These two papers are followed by an article by Mr. Goldbeck giving the results of a series of investigations conducted on stone sand in our research laboratory, in which it is pointed out that proper attention to the gradation of stone sand removes some of the more important objections which have been raised with regard to its use. These three articles constitute, in our opinion, one of the most valuable collections of data and information yet available on this subject.

the fine and coarse aggregates. At this point, it might be well to state that Knoxville, being located on the Tennessee River, is well supplied with sand and gravel plants which furnish a high grade of crushed river gravel and washed sand. These river products had passed all specifications throughout the State and had been used extensively in all types of construction. The Holston Quarries' crushed limestone, to be furnished by the American Limestone Company, was also a familiar material and acceptable for the rock. This company also wished to furnish the fine aggregate, and proposed to use their dolomite rock-sand, a by-product of the American Zinc Company, at Mascot, Tennessee. This sand had never been used on a major project and was practically unknown in the construction field. It had passed the State's specifications for highways and had been given an experimental test on some paving work; however, the State would not allow it to be used on any of its structures. The reason for this was certain conditions of disintegration which had developed on bridges and other structures in Nashville, where limestone had been used for the fine aggregate. All kinds of rumors were out, even to the fact that the Mascot sand had been used on these very structures. This was later disproved as was also a case in Knoxville—the Asylum Avenue Viaduct handrails, where it was said the Mascot sand had been used. These handrails had crumbled completely and had to be replaced. Investigation showed this to be caused either by too much limestone dust or too little cement. In all probability an excessive amount of the limestone dust, with perhaps some free lime present, weakened the cement paste from the beginning. Had compression tests been taken on this concrete at the time it was poured, it surely must have shown very poor strength.

At any rate, the problem was whether or not to use Dolomite sand, of which so little was known, in so important a structure as the Henley Street Bridge.

<sup>1</sup> Presented at the Fifteenth Annual Convention of the National Crushed Stone Association, held at the William Penn Hotel, Pittsburgh, Pa., January 19-22, 1932.

Specifications called for the usual qualifications of sand, with the following special requirements:

Passing the three-eighths (3/8) inch mesh sieve	100%
Passing the four (4) mesh sieve not less than	85%
Loss by Elutriation not over	3%
Fineness Modulus 2.4 to 3.8.	

Our own sieve analysis tests of the dolomite met with these specifications. We decided, however, to obtain samples of both the Tennessee River sand and the dolomite sand and have comparative tests made of these two materials by some responsible laboratories. The Pittsburgh Testing Laboratories and Froehling & Robertson, Inc., were selected to make the tests and were furnished representative samples of the two materials.

The Pittsburgh Laboratories' tests were mostly chemical and compared favorably with the chemical tests which we already had, made by the Nichols Laboratories at Knoxville, and also compared favorably with the chemical tests furnished us by the American Limestone Company, made in their own laboratories and covering a three months' period of time. The conclusion of the Pittsburgh Testing Laboratories was as follows:

From the chemical analysis of the dolomitic sand, we see no reason to fear decomposition or other deterioration with age, when it is incorporated as fine aggregate in concrete.

They suggested a slight change in the grading by adding to the smaller sizes, and also approved the Tennessee River sand should we desire to use the same.

The Froehling & Robertson's tests covered the physical features of the two materials (as herein outlined:)

	Dolomite Sand	Tenn. River Sand
Fineness Modulus --	2.9	2.5
Elutriation -----	0.65%	2.0%
Tensile Strength		
1-3 Mortar Briquettes		
Strength ratio to standard of 10.3% water:		
7 days -----	125.4%	100.67%
28 days -----	126.5%	100.73%
	Dolomite Sand	Tenn. River Sand
Compressive Strength		
1-3 Mortar 2"x4" Cylinders		
Water cement ratio .80--	4235 lbs.	3328 lbs.
Water cement ratio .933--	3387 lbs.	2697 lbs.
Water cement ratio 1.0---	2621 lbs.	2607 lbs.

From the above you will note the dolomite sand proved the better in every instance.

We were now satisfied with the strength which we were sure to obtain from the dolomite sand, but the question of durability arose and there was nothing to guide us in arriving at a solution for this phase of the work. The American Zinc Company had built some concrete foundations which were 15 to 20 years old. Although they had been constructed in a haphazard manner from this sand and were an inferior grade of

concrete, these specimens were in fairly good condition. We were having a sodium sulphate test made for soundness by the Froehling & Robertson Laboratories, but this would not be completed for some thirty days and the contractors were almost ready to pour concrete.

As a final safeguard, we decided to study the problem from a geological standpoint. Dr. L. C. Glenn, at the head of the Geological Department of the Vander-



View of Henley Street Bridge, Knoxville, Tenn.

bilt University, was taken into consultation, and his report, parts of which are herein stated, was very comprehensive and embodies a purely chemical and geological examination and discussion.

Rain water carries small amounts of carbonic acid obtained from the air, and ordinary river water usually also contains humic and other organic acids formed by the decay of vegetation. The problem then is to the effect of these various acids on the life of the concrete, through the possibility of chemical attack on the dolomite of the fine aggregate.

In the first place, the carbonic and other acids in the river water that might attack bridge piers, would probably be kept largely neutralized at ordinary stages by reaction both with the limestones over which the streams of East Tennessee flow and with the lime held in solution in the water. Only during floods when dissolved lime salts are much diluted and organic acids of decay greatly increased would there be much chemical attack by the river. The other mode of attack would be by the carbonic acid in the falling rain.

When we turn to past experience by engineers in the use of such dolomitic materials we find practically nothing to guide us, because it is very rarely that circumstances are such as to make it economically practicable to crush, wash and screen dolomite for such use, in competition with other materials that may usually be gotten more cheaply.

The nearest approach is in the use of limestone screenings for fine aggregate. Such material has been used satisfactorily in many places where siliceous sand or other material was not readily available. It is not regarded as being as good as siliceous materials because of its more easy solubility, though this, as above remarked, has not prevented its being used. The problem must then be approached from the chemical standpoint, and an opinion on probabilities rather than on experience.

The following summary of chemical analyses covering a three months' period is accepted as fairly representing the composition of the materials involved, and shows about 9% insoluble, 1% iron and alumina oxides, 54% calcium carbonate, 36% magnesium carbonate and a trace, about 0.1%, of zinc sulphide.

The 9 per cent of insoluble material is largely or entirely siliceous matter, mostly in the form of chert, particles of which were found in the microscopic examination of the material. Such material as this could do no harm. The iron and alumina being very low, about 1 per cent, shows that there is very little clay and very little pyrite. Both of these would be injurious if present in any considerable quantity. No clay was found in the microscopical examination and rare minute particles of pyrite were found mostly in the residues after solution. Other geological reports show a rarity of pyrite in the mineralized zone around Mascot. Pyrite in any quantity would be especially injurious as it readily breaks down and yields hydrated iron oxide and sulphuric acid, and the acid attacks the lime present and forms hydrated calcium sulphate or gypsum, and swelling and disintegration would result. Canadian mines with iron and copper sulphide tailings have tried using them in concrete with unsatisfactory results. The absence of such sulphides in the Mascot dolomite eliminated this cause for rejection.

Zinc sulphide is present in the analyses in the amount of 0.1 of one per cent. Zinc holds to its sulphur in sphalerite far more strongly than iron holds to its sulphur in pyrite; or, in other words, the zinc sulphide is far more stable than the iron pyrite and this, along with the very small quantity of it found here, robs it of any danger.

With these minor constituents disposed of, we find that the bulk of the material is the carbonate of lime and magnesia, or dolomite, and our main problem really is as to how this dolomite will resist solution.

Dolomite is known to be much less soluble than limestone; in fact, one of the most prominent tests for distinguishing between calcite and dolomite is the resistance of dolomite to solution in dilute acids to which the calcite readily succumbs. When placed in the concrete as fine aggregate, the dolomite would be attacked much more slowly than would be the limestone of the coarse aggregate or the calcium carbonate in the ce-

ment paste formed as the calcium aluminates and silicates decomposed in the setting of the cement.

Limestones dissolve at varying rates. Some used in smooth faced masonry of canal locks are reported to have shown an inch or inch and a half of solution after 60 to 80 years' use.

By the above line of reasoning, the conclusion was reached that the dolomite sand, of the type furnished by the American Limestone Company, if properly washed and screened, would be safe to use as fine aggregate for the concrete of the proposed bridge.

Following this geological study came the results of the sodium sulphate soundness tests and reassured us that the geological judgment was sound. The dolomite sand having a water cement ratio of .933, with compressive strength at 28 days of 3387 lbs., showed 16 cycles to obtain complete disintegration, whereas the Tennessee River sand having a water cement ratio of .800, with practically the same compressive strength of 3328 lbs., showed 15 cycles to obtain complete disintegration.

Thus, after being satisfied with the quality of the materials, came the real important part of obtaining and controlling good concrete throughout the job. Specifications call for the different classes of concrete, as follows:

	Water-Cement Ratio	No. Bags of Cement	28 days strength
Class "A" -----	6.3 gals.	6 bags	2500 lbs.
Class "S" -----	5- $\frac{1}{2}$ gals.	6- $\frac{1}{2}$ bags	3400 lbs.
Class "F" -----	5- $\frac{1}{2}$ gals.	8 bags	3400 lbs.

Class "A" concrete was to be used in the piers, Class "S" was used in all other parts except in the handrails and Class "F" in handrails only.

Cumberland Portland cement was used and was given the usual A. S. T. M. tests at the bins. All materials were accurately weighed for each batch of concrete at the central mixing plant and the water was accurately measured, making due allowance for the free moisture contained in the aggregates. Design sheets were kept on each day's pour and were filed as records of all details of the concrete mix. Control tests were made from every pour and throughout the job as deemed to be needed. These were the usual tests of the A. S. T. M., the most important of which were our concrete cylinders. These cylinders were made at the central mixing plant and also at the site, and were broken at the end of seven and twenty-eight days at the University of Tennessee Laboratories.

The averages of the results of these tests were very satisfying and show that we obtained excellent concrete throughout the work.

The average strength of our Class "A" concrete was 3061 lbs. with a 5.5 inch slump. The average strength of the Class "S" was 3809 lbs. with a 5.8 inch slump. At this point, I want to state that this slump measure

(Continued on page 17)

# Use of Manufactured Stone Sand<sup>1</sup>

By ROBERT L. FOX

City Engineer, Bethlehem, Pa.

## Introduction

A construction material which has given excellent results and has saved \$134,000.00 for the builders, besides returning a profit to the industry, all within a territory with a radius of about five miles, merits consideration and further development by all those interested in bringing about further economies in capital and current expenditures.

Some one has said that "service" is the rent one pays for the space one occupies upon this earth. Organizations, such as have convened here this morning, owe their very existence to the service they render to their membership and, through them, to the public. My experience and investigation in the use of a by-product of your industry has convinced me that your organization has a golden opportunity to render a worthwhile service, not only in expanding and returning larger dividends to your membership, but also in the saving of substantial amounts to the buying public.

It is folly to conserve in first cost if the maintenance expense overbalances the annual return upon the amount saved, but it is wisdom and good business if such conservation renders the same service and returns larger dividends.

Through the use of stone sand in concrete street paving during the past six years, the City of Bethlehem has saved in first cost an amount such that if properly invested would return sufficient funds to annually pay for maintaining the joints.

The outstanding features of the Bethlehem streets, where this material has been used, are as follows:

- (a)—Through a higher strength mortar, which is natural to this particular stone sand when mixed with good cement using suitable consistency, the streets are opened to traffic in five days.
- (b)—They do not scale (except in a few places involving a small yardage and due to surface freezing from improper protection during cold weather).
- (c)—The mortar adheres to the surface stone after years of service.
- (d)—Their riding qualities have improved and kept pace with the better riding qualities that have been secured in highway construction from year to year and compare favorably with concrete paving constructed elsewhere in this district.

(e)—Since an improved design was adopted in 1928 they have been free from contraction cracks.

(f)—They do not require additional help in finishing.

(g)—Laboratory tests have shown that the mortar absorbs less moisture from immersion than mortar made from either the Standard Ottawa Sand or the Delaware River Sand.

To ascertain the extent to which this product is used and the experience of others, the writer sent a questionnaire to highway departments of twenty-nine states and their answers are not only of interest, but of great value to this subject.

Fourteen state highway departments out of twenty-nine permit the use of manufactured stone sand in amounts varying from 25 to 100 per cent of the total sand requirement.

Four highway departments not permitting its use state there is no demand for its consideration in their territory as there is plenty of natural sand available at a price at which manufactured sand could not successfully compete.

Twelve highway departments not permitting its use, state that they have not performed experiments to be able to judge intelligently from actual observations.

Eleven highway departments out of the twenty-nine have made tests ranging from field observations and laboratory tests to the actual construction of a section of a road for experimental purposes.

Observations from the highway departments are recorded as follows:

## Maryland

The Commission constructed a one-half mile test section in 1930, of a concrete road in which a prepared stone sand was used in place of natural sand. The balance of the contract was constructed with natural sand complying with our specifications. Cores taken from the two sections of this contract, indicated that the strength of concrete produced by the stone sand was considerably less—as I remember it, six or seven hundred pounds per square inch in compression at 28 days—as compared with the concrete produced from natural sand. These were cores taken from the completed roadway and were not specially made specimens.

The Commission has cooperated with one producer of stone sand in conducting experiments to check the accuracy of the result obtained in (c). These experiments consisted in making specimens for compression and modulus of rupture tests, and the indications at seven and twenty-eight days were that the natural sand produced a stronger concrete than the stone sand. The reason for this was apparently found in the fact that to obtain a certain workability as measured by the slump test, it

<sup>1</sup> Presented at the Fifteenth Annual Convention of the National Crushed Stone Association held at the William Penn Hotel, Pittsburgh, Pa., January 19-22, 1932.

was necessary to use a higher mixing water content with the stone sand than was necessary with the natural sand and that this higher water content produced a concrete weaker both in tension and in compression.

### Tennessee

Excellent results have been obtained by the use of stone sand in concrete pavement.

We have no data in our files with reference to experiments or observations where stone sand has been used. We made field tests and used this material in projects, which were entirely satisfactory.

### Vermont

Our experience with stone sand indicates that it is apparently satisfactory in so far as strength is concerned but we are still skeptical of its value in pavement due to the difficulty in securing properly graded stone sand. Our producers have difficulty in controlling the grading of this material and it is not at all unusual to have stone sand contain an excess of very fine material on the one hand or twenty to twenty-five per cent stone chips on the other. Another difficulty encountered in the securing of dense high grade concrete is the absence of the intermediate size particles in this type of sand. In other words, it is not uniformly graded. Most of these objections are overcome by combinations using both stone sand and natural sand, and we have no objections to the use of stone sand when combined with properly selected natural sand.

### Connecticut

#### Report A

This Department has never used to any great extent sand prepared from screenings. We have made numerous laboratory tests using various combinations of sand prepared from trap rock screenings with very excellent results. Up to the present time none of the commercial quarries have seen fit to develop this branch of the business but I believe if properly handled, a very satisfactory product could be obtained. The use of trap rock screenings produced a very sticky mortar rather hard to finish. This condition was greatly improved by an admixture of local sand.

#### Report B

I believe that a very satisfactory sand can be obtained from crushed stone screenings if produced from a hard durable stone.

### Ohio

It has been my observation that limestone sand meeting the requirements of our specifications is a satisfactory fine aggregate for concrete.

My answer to this inquiry appears in paragraph C. In addition I might mention that limestone sand meeting the requirements of our specification has been used satisfactorily in several concrete pavement jobs in Ohio this year. Further, you probably know that the Ohio State University Stadium, a concrete structure containing approximately 70,000 cubic yards of concrete was built using limestone sand as the fine aggregate. The stadium is an excellent example of good concrete.

### New Jersey

Until recently we have never been able to secure a stone sand that would have the composition required by our specifications. The sand recently approved had such a composition and is mine tailings specially prepared from a mine in the vicinity of Dover, N. J.

Stone sand will no doubt give a very good strength but unless it is properly graded it will lower the workability of the concrete. Also, unless properly graded the density of the concrete will likewise be decreased.

A number of years ago we used stone sand in a concrete pavement. This pavement remained in good condition for a few years and gradually began to disintegrate on the surface. This disintegration was not always accompanied by cracking but appeared to be caused directly by the porosity of the concrete, for the concrete below the zone of decomposition is in good condition today.

Also, other sections of the same pavement constructed with a well graded bank sand did not develop the same defects as were noted in the section constructed with stone sand.

Personally, I would not recommend the use of stone sand for it is quite safe to assume that it will very seldom be so graded as to give the workability desired.

### Illinois

Several years ago we constructed one small section of pavement using screenings, and I hardly think that our experience with this one section, especially since the work was performed under specifications entirely different from those which we are using at the present time, can be taken as evidence either for or against this product.

### Michigan

We have built only one small job using clean prepared "stone sand" as the fine aggregate. In this instance it was reported that the concrete was somewhat harsher than is customary with natural sand, but that a very satisfactory surface was obtained. The texture of the surface was somewhat more granular than we ordinarily obtain. I am enclosing a copy of the specification under which this material is furnished.

In one location natural sand conforming to our ordinary requirements is relatively scarce, and we have, at various times, used a combination of a fine local bank sand with coarser clean stone screenings which are obtained as a waste product in the treatment of copper ore. This mixture also gives a rather harsh working concrete, although the fine natural sand helps in this regard.

We are not averse to the use of properly prepared stone sand meeting the requirements of the enclosed specification, provided the rock itself is thoroughly sound and meets the quality test requirements for coarse aggregate for concrete pavement. This specification does not, at the present time, appear in our standards, but may be especially approved for use on specific projects.

### Massachusetts

As to my opinion upon the use of crushed stone sand, I would say that if used at a washing plant where all the material passing a 100 mesh sieve would be washed out and the remainder would pass our requirements both as to grading and strength, I could see no objection to its use.

### New York

At the present time we are revising our specifications for the year 1932 and expect to revise somewhat the sizing of artificial sand. We have not as yet, however, made a definite decision as to what screen analysis may be required. Last year our specifications required that only 40% of artificial sand should pass the No. 14 sieve. The results we obtained with the use of an artificial sand meeting this minimum requirement were not very satisfactory. However, we did have, from two other sources, an artificial sand about 60% of which passed the No. 14 sieve and from which we obtained much better results. It is our purpose, for the year 1932, to require that at least 60% shall pass the No. 14 sieve and we are of the opinion that it will greatly improve the product. Whether or not it will be entirely satisfactory as a result of this change in gradation, I am, at this time, unable to advise.

## Virginia

In reference to the use of crushed stone sand as fine aggregate for concrete, we have found that when this material alone is used the concrete is entirely too harsh for proper workability unless an excessive amount of water is used. This, of course, raises the water cement ratio. An unsatisfactory finish also has been obtained when using stone sand only. For these reasons, it has been our practice to use 50% commercial sand and 50% stone sand wherever economic conditions necessitated the lowering of concrete costs due to the high freight charges on commercial sand.

So far as I know, we have used stone sand exclusively on only one job. This was a large culvert and difficulty was encountered in obtaining the proper finish on the concrete. The experiment was not repeated. Until lately, the only stone sand that has been available in this State was limestone sand. While limestone sand makes a mortar of unusually high compressive strength, the mortar is extremely brittle and tends to spall and fracture rather easily under impact.

## Georgia

### Report A

Adequate strength may be obtained with durable crushed stone sand. In fact, very high tensile strengths are shown for limestone screenings, but concrete made of limestone screenings is not sound. Disintegration is relatively rapid. Limestone as coarse aggregate is entirely satisfactory, but when crushed to sand sizes it becomes partially soluble. This department will not permit limestone screenings for sand in concrete.

Granite screenings are difficult to finish in concrete, but can be used satisfactorily where gradation is accurately controlled.

### Report B

One mile of 9-6-9 concrete pavement 20 feet wide composing 50-50 mixture of washed sand and granite screenings laid this fall; results satisfactory. One-half mile 100% granite screenings laid this fall; results fair. Hair cracks developed in surface soon after finishing, but may have been due to other factors.

## West Virginia

Stone sand has been used very little in this State, for the reason that natural sand is plentiful and available to almost all parts of the State. In places where stone sand has been used, it has given satisfaction.

## New Hampshire

Providing the crushed "stone sand" is of a siliceous nature I could see no reason why this material could not be properly used for fine aggregate for concrete.

## Minnesota

I think that sand made from crushed stone is suitable if washed clean and properly graded. I think that on account of the angular particles less of this sand could be used with a given water cement ratio than would be the case with natural sand. This is on account of workability. The original stone must be sound and durable.

## Kansas

In our opinion, crushed stone screenings are satisfactory for use as a fine aggregate in concrete from a strength standpoint, but they produce a concrete which is very difficult to finish and is not durable because of a lack of density.

## Texas

On the modern traffic, which is carried almost entirely upon rubber, the factor of wear in concrete paving is not of great consequence provided the mortar used is of such nature that it will not wear out appreciably under these conditions. However, there is in this State a constantly diminishing proportion of steel tired traffic, which, of course, is much harder on the surface of concrete pavement than the rubber tired traffic. It has been our observation that upon very lean concrete, notably two sacks per cubic yard, the effect of even rubber tired traffic



Center Street or Bath Pike, Bethlehem, Pa., in which washed stone sand was used exclusively as fine aggregate

is such as to sweep the mortar off of and from between the topmost particles of coarse aggregate. It is difficult to determine from field data just what the minimum requirement for wear resistance in a mortar should be. Regardless of its resistance to wear when made into concrete mortar, I feel that crushed stone sand would have very little value as fine aggregate for concrete pavement since by its extremely harsh nature it would undoubtedly increase a water-cement ratio necessary to maintain the given workability with a constant cement factor. This last condition has made it appear to us to be undesirable to conduct tests with an idea of using crushed stone sand.

## Missouri

Generally speaking we would not favor or encourage the use of crushed stone sand in competition with a good natural river sand even where a good sound grade of stone sand could be obtained because it would produce a harsher working mortar than a properly prepared natural sand.

We question whether it would be economically feasible for many plants to produce a properly graded stone sand to compete with a river sand because of the need and cost of equipment to produce a uniform product. Certainly we cannot conceive of any advantage stone sand might ever have to justify paying more for it than river sand. River sand as a rule can be produced cheaper and most modern plants can control quite definitely the uniformity of the product.

If sound, well graded and uniform stone sand can be obtained in a locality where river sand cannot be economically obtained, its use would probably be justified.

We have no actual experience in the use of crushed stone sand. However, in the Joplin District of this State, chat (a cherty material) refuse from lead and zinc ore is ground into sand. The angularity of this material produces a rather harsh

mortar which requires additional cement or a suitable admixture to secure the desired workability. We have a few other plants producing crushed chert gravel which has hard, sharp and angular particles. In order to improve the workability of the mortar when this type of sand is used, we limit the amount of material above 1/8 inch to five per cent and in addition require the use of additional cement or an admixture.

For the above reasons we prefer a natural worn or rounded river sand to any crushed material for use in concrete pavement because we believe greater durability and density in mortar is secured at a lower cost.

### California

The main conclusions drawn regarding the use of manufactured sand are:

That both production of sand and handling of the concrete are quite costly. Due to this, contractors seldom figure on using manufactured sand when other material is readily available.

That the material usually furnishes a rather harsh working concrete and the mix requires skillful handling in order to obtain satisfactory results.

### Comments Upon the Opinions Set Forth in the Questionnaire from 29 States

1. It is to be observed and is rather significant, that the replies from every state highway department, having either conducted experiments or having used stone sand, approve its use either entirely or else as a percentage of the total sand requirement.

2. It is to be observed that the principal criticisms mitigating against its use are:

- (a) Difficulty in securing a properly graded product.
- (b) That which is principally due to lack of proper grading—poor workability.
- (c) That which is in many cases largely due to gradation—less compressive strength than natural sand.

3. The apparent lack of interest upon the part of the stone industry in some states in interesting the state authorities in the use of this product, as it is found that the engineering departments have not performed experiments due to the non-existence of suitable material for such purposes.

### Experience as to the Use of Stone Sand in Bethlehem, Penna.

Since 1924 there have been completed 43 concrete street paving contracts involving 230,000 square yards of paving equivalent to 22 miles of highway 18 feet wide, upon which washed manufactured limestone sand has been used as the total sand requirement.

Before this sand was approved, extensive tests were made at the Fritz Laboratory, Lehigh University, to determine its strength, absorption and grading. A comparison was made with the Standard Ottawa, Succasunna (a Delaware River product) and limestone sands.

The average of six mortar 1:2 seven day tensile and compressive tests were as follows (in pounds per square inch):

	Tensile	Compressive
Standard Ottawa .....	268	1510
Succasunna .....	212	1450
Stone Sand .....	298	2200

The corresponding 28 day tests were as follows:

	Tensile	Compressive
Standard Ottawa .....	450	4155
Succasunna .....	363	2790
Stone Sand .....	584	4965

### Sieve Analysis of the Stone Sand

(Per cent of sample coarser than a given sieve)	
Sieve Mesh	Stone Sand
100	95.7
48	88.1
28	77.0
14	62.6
8	35.7
4	1.4
3/8	0

Fineness modulus 3.60

### Absorption Test

Two blocks 8 x 3 3/4 x 2 1/4 inches were made, cured for 24 hours in damp closet and then heated at room temperature to constant weight. They were then immersed in water.

Total gain in 72 hours of immersion 6.95%.

### Paving Practice at Bethlehem

For the past three years, Bethlehem has required the contractor to make five-day compressive tests at an approved laboratory upon concrete cylinders from each 2,000 square yards of paving. Fifty-three sets of three cylinders each of 6 x 12 cylinders have been tested and invariably showed a crushing strength exceeding 2,500 pounds per square inch in five days. Slump tests taken at time the cylinders are made with between four and five gallons of water per sack of cement, (varying with moisture content of sand) invariably range between the limits of 1 1/2 to 3 inches.

During the year 1930, several contracts were performed and of special interest were two contracts awarded to the same contractor, upon one of which natural sand was used and the other washed limestone crushed sand was required. The same equipment and finishers were used upon both contracts and it is of interest to record that, as far as can be ascertained, there is no difference in riding qualities, and although the artificial sand is harsher, yet without additional finishers, the maximum output of finished work per day was in no way handicapped as a result of the sand. The first few days the finishers who were accustomed to natural sand, complained as to its workability, but after a few days' experience they became accustomed to its use. When it is realized that the one contract upon which natural sand was used was tested by the State Highway Department for roughness and showed, through the bumpometer test, an unevenness of about

eight inches per mile (a low figure), it can be safely concluded that with the stone sand used in Bethlehem as good riding qualities may be secured as when natural sand is used.

### Tests Upon Cores Drilled from Completed Work

Through the courtesy of the Pennsylvania Highway Department, two series of cores were drilled during the latter part of 1931 from concrete paving placed in 1922-1924 and during 1930 wherein natural sand and limestone sand were used and the compressive tests from these cores are as follows:

Limestone crushed sand concrete constructed during 1924, an average of 3,849 pounds per square inch.

Natural sand concrete constructed during 1922, an average of 4,477 pounds per square inch.

Limestone crushed sand concrete constructed during 1930, an average of 3,689 pounds per square inch.

Natural sand concrete constructed during 1930, an average of 4,206 pounds per square inch.

This core test is not conclusive in view of the fact that for the older roads different stone, cement and methods were used and these results are submitted only for informative purposes.

### Conclusion

The viewpoint of engineers, architects and contractors unfamiliar with this product, with whom I have come in contact, is, in general, skeptical as to its use. This seems to be based upon their belief that they will not secure a properly graded product, requiring an unsatisfactory water content and increasing the cost of finishing. In general, they do not question the strength of the finished product.

It would, therefore, seem a matter of wisdom for the producers considering the marketing of this valuable by-product or enlarging the field in which they are now selling, to ascertain by exhaustive test the proper grading of their material for best results.

When it is realized that the Bethlehem Mines Corporation has, in the last few years, marketed 1,012,000 gross tons of commercial concrete stone, and has during the same time sold 244,000 gross tons of limestone sand without any especial treatment except washing, it is evident that this is a field in which many in the crushed stone industry are warranted in expending considerable thought, time and effort in not only rendering a service to the public, but that which is of prime importance in any business, a larger return upon the capital invested.

In the preparation of this paper the writer acknowledges the valuable services and thought rendered by

the following engineers: H. S. Mattimore, F. C. Lang, C. H. Moorefield, Bert Meyers, A. W. Dean, C. B. Bryant, Wm. J. Titus, R. L. Cochran, E. C. Lawton, Shreve Clark, T. C. McEwen, L. D. Barrows, W. W. Mack, R. I. Rowell, J. E. Boyd, W. W. Zass, C. P. Fortney, T. G. McCrory, J. A. Macdonald, S. H. Probert, Wallace F. Purrington, R. R. Litehiser, J. L. Bauer, V. L. Glover, H. Allen, W. H. Wood, T. H. Cutler, T. E. Stantan, and W. J. Emmons.

### TEST MADE BY TESTING LABORATORY OF A WELL-KNOWN PORTLAND CEMENT COMPANY

October 13, 1930.

In order to form an opinion of the Bethlehem Mines Sand as fine aggregate for concrete, we made up the sample you sent us in a 1:2:3 mix by volume, in comparison with a similar mix in which Warner sand from Morrisville, Pa., was used.

The Bethlehem sand was found to have a fineness modulus of 3.16, a color of 0 in the sodium hydroxide test and a unit weight of 112.6 lb. per cubic foot, dry and rodded. The coarse aggregate used in the concrete was local crushed limestone, graded up to 1½" and had a unit weight of 93.5 lb. per cu. ft.

Only two batches were made up, one with each type of sand, and out of these a 6" x 12" cylinder was made for test of compressive strength at 7 days. The data of the tests are given in the following table:

Quantities of Materials per cu. yd.	Bethlehem Mines Sand	Warner Sand
Cement	1.53 bbl.	1.61 bbl.
Sand	12.25 cu. ft.	12.86 cu. ft.
Stone	18.30 cu. ft.	19.25 cu. ft.
Water	44.8 gal.	40.3 gal.
W/C	0.97	0.84
Flow	49%	52%
Workability	Satisfactory, but not as good as the other.	Good

Compressive Strength: 7 days (lb./sq. in.)	2750	2790
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The most striking point brought out by the foregoing comparison is that the concretes have equal strength and consistency, but very different water-ratios. The workability of the Bethlehem sand is, of course, not quite on a par with the other, but on a basis of equal strength the Bethlehem mix is the more economical of the two.

### Dolomite Sand in Concrete for the Henley Street Bridge

(Continued from page 12)

was taken at the central mixing plant and decreased from ½ inch to 1 inch by the time it reached the site. These strengths gave us 400 pounds more per square inch than the specifications called for. In no instance did our concrete fall below the designed strength.

The Portland Cement Association was very helpful to us, and sent its Mr. Flodin, of its Structural and Technical Bureau, who was with us for two weeks and closely observed everything in connection with the concrete.

In conclusion, it is gratifying to state that the dolomite sand came up to all of our expectations, gave us a plastic mixture with no segregation and placed nicely in the forms. We had very little honeycomb and the concrete finished smoothly, was properly cured, and we hope will be there from now on.

## Use of Manufactured Stone Sand—Appendix "A"

### Compilation of Answers from Highway Departments on the Use of Manufactured Stone Sand

STATE	USE PERMITTED	OPINION	OBSERVATIONS
Iowa	No Abundance of natural sand at \$.40 per ton.	No experience.	None
Massachusetts	No Except bank run gravel crushed.	If washed removing all material passing 100 mesh and proper grading and proper strength believe it would be satisfactory.	No experiments.
Maryland	Permit mixture not to exceed 25% and control of amount passing 100 mesh.		One half mile test road. Artificial sand showed less strength in compression. Higher water content required.
Indiana	No	Not qualified.	No experiments nor extensive studies.
Nebraska	No	No experience.	
New York	Yes Limited amount.	Under former grading results not very satis- factory.	Experimenting to secure proper grading.
Virginia	Yes Up to 50% mixture.	When used up to 100% too harsh for worka- bility requiring excessive amount of water. Limes one sand mortar too brittle tending to spall and fracture.	Used upon a large culvert. Difficult to se- cure proper finish.
Tennessee	Yes	Excellent results have been obtained.	Field tests which were satisfactory.
Maine	Yes Up to 50% as mixture and from hard durable rock, washed and dustless.		
Delaware	No		Unnecessary as plenty of natural sand available.
Vermont	Permit 33% as mixture.	Satisfactory from strength viewpoint. Skep- tical due to inability to secure proper gra- dation.	
Georgia		Adequate strength may be secured with durable stone. Limestone sand not sound.	One mile of road with 50-50 mixture of granite screenings. One-half mile with 100% granite screenings.
Arkansas	No	None	None
West Virginia	Yes	Where used given satisfaction.	None
Washington		No occasion to use.	None
Connecticut		If produced from hard durable rock, believe satisfactory.	Laboratory tests with very excellent re- sults.
Oregon		Higher cost precludes its use.	
New Hampshire	Probably would permit.	Of siliceous nature, believe it to be satis- factory.	None
Ohio	Yes	Limestone sand satisfactory.	Observations satisfactory.
New Jersey	Recently approved a stone sand from Dover.	Will give good strength. Unless properly graded will lower workability and decrease density. Does not recommend on account of grading.	Yes
Minnesota	No	Suitable if clean and graded. Stone must be sound and durable.	None
Illinois	No		One section of road.
Kansas	No	Not durable from lack of density and diffi- cult to finish.	Field and observations only.
Texas	Not in paving. Permit 50% in structural concrete.	Little value due to harshness and increased amount of water required.	None
Missouri	Yes Although their actual use has never been approved.	If sound, well graded and uniform sand can be produced where river sand is not economical, its use would be justified. In general, does not approve.	No actual experience.
California	Yes Provided if of a workable mix.	High tensile strength. No objection to its use.	Produces harsh working concrete, requires skillful handling.
Michigan	May be especially approved if meeting requirements.	Not adverse to properly prepared from thor- oughly sound rock.	One small job satisfactory surface secured —concrete harsh.
South Carolina	No	Little experience.	One section of road under construction.

## Appendix "B"

## Laboratory Tests on Manufactured Stone Sand

(Tests made at Fritz Engineering Laboratory, Lehigh University, on Limestone Screenings and Succasunna Sand, submitted by R. L. Fox, City Engineer of Bethlehem, Apr.-May, 1924.)

## TENSILE TESTS—7 DAY

Specimen No.	Ottawa Sand		Succasunna Sand		Limestone Screenings	
	1-3	1-2	1-3	1-2	1-3	1-2
1	201	285	143	172	200	275
2	203	287	140	203	226	315
3	186	266	145	212	190	338
4	210	240	142	235	216	292
5	186	254	140	213	270	274
6	181	290	140	240	268	298
Aver.	194	268	141	212	230	298

## COMPRESSIVE TESTS—7 DAY

Specimen No.	Ottawa Sand		Succasunna Sand		Limestone Screenings	
	1-3	1-2	1-3	1-2	1-3	1-2
1	865	1530	620	1490	1700	2190
2	945	1630	785	1590	1640	1900
3	890	1680	605	1285	1650	2340
4	760	1390	610	1455	1510	2540
5	920	1330	925	1450	1380	2070
Aver.	875	1510	710	1450	1570	2200

## TENSILE TESTS—28 DAY

Specimen No.	Ottawa Sand		Succasunna Sand		Limestone Screenings	
	1-3	1-2	1-3	1-2	1-3	1-2
1	297	425	214	317	554	609
2	270	476	268	339	552	612
3	354	430	230	429	604	545
4	300	444	235	397	556	609
5	297	488	280	411	587	544
6	311	441	270	407	582	594
Aver.	305	450	250	363	573	584

## COMPRESSIVE TESTS—28 DAY

Specimen No.	Ottawa Sand		Succasunna Sand		Limestone Screenings	
	1-3	1-2	1-3	1-2	1-3	1-2
1	1620	4160	1220	2940	3840	5260
2	1120	3470	1770	2500	4120	4670
3	1640	4130	2220	2720	4120	4680
4	1490	4560	1460	3200	4070	5060
5	2240	4460	1570	2600	4440	5150
Aver.	1620	4155	1670	2790	4120	4965

SIEVE ANALYSIS OF AGGREGATES  
Percent of Sample Coarser Than a Given Sieve

Sieve Size	Size of square openings ins.	Succasunna Sand		Limestone Screenings	
		# 1	# 2	# 1	# 2
100 mesh	.0058	96.3	95.8	95.7	95.8
48 "	.0116	76.4	80.7	88.1	87.1
28 "	.0232	37.6	38.1	77.0	75.3
14 "	.0460	13.1	13.7	62.6	61.1
8 "	.0930	.2	.2	35.7	34.6
4 "	.1850	0	0	1.4	1.3
3/8 "	.3710	0	0	0	0
Fineness Modulus		2.23	2.28	3.60	3.55

% Retained on 50 mesh sieve	Succasunna 100	Limestone Screenings 90
% Passing 1/4" sieve	78	99

## ABSORPTION TEST

Two blocks 8" x 3 3/4" x 2 1/4" were made, cured for 24 hours in damp closet and then heated at room temperature to constant weight. They were then immersed in water.

Limestone weight (dry)	2560 grams
Succasunna weight (dry)	2259 grams

	After Immersion	Weight Grams	Grams Gain
Limestone	24 hours	2672	166
Succasunna	24 hours	2437	178
Limestone	48 hours	2674	168
Succasunna	48 hours	2440	181
Limestone	72 hours	2680	174
Succasunna	72 hours	2444	185

Limestone	Total gain in 72 hours—174	6.95%
Succasunna	Total gain in 72 hours—185	8.20%

## Help!

"I married a widow who had a grown daughter. My father visited our house very often and fell in love with my step-daughter and married her. So my father became my son-in-law and my step-daughter my mother, because she was my father's wife. Some time afterwards my wife had a son: he is my father's brother-in-law and my uncle, for he is the brother of my step-mother. My father's wife, namely my step-mother, had a son: he is, of course, my brother, and in the meantime my grandchild, for he is the son of my daughter. My wife is my grandmother because she is my mother's mother. I am my wife's husband and grandchild at the same time, and as the husband of a person's grandmother is his grandfather, I am my own grandfather."—*Florida Highways*.

A mother asked her daughter, who had been out the night before, if she had been a good girl. The daughter answered, "Yes." Mother: "Were you a very good girl?" Daughter: "Yes, I was, mother, and to prove it, I brought you a Gideon Bible."—*Exchange*.

# An Investigation of the Gradation of Stone Sand for Concrete

By A. T. GOLDBECK

Director, Bureau of Engineering,  
National Crushed Stone Association

Stone sand for use as a fine aggregate in concrete in place of natural sand is becoming an increasingly important product. There are many places where good, natural sand does not exist but where stone sand may be produced and sold at a reasonable price.

It should be self-evident that stone sand should be manufactured only from sound durable stone and, possibly, the product from all quarries may not be suitable for this purpose. Stone sand is angular in shape, more so than most natural sands and consequently the question of proper gradation is important, for upon the gradation hinges the question of strength and of workability of the concrete.

In view of the growing use of stone sand it was thought advisable that we conduct a preliminary investigation to determine the gradation which producers should aim to obtain in order that their product might produce the highest strength concrete at the lowest cost and with suitable workability.

## Method of Test Procedure

For the purpose of our laboratory investigations we prepared stone sand making use of limestone sold in the Washington market. This is an exceptionally good grade of stone having the following characteristics: Percentage of wear, Deval Abrasion Test, 3.3 and Apparent Specific Gravity 2.77. This limestone was also used as the coarse aggregate in the various concrete mixtures used in the test.

The stone sand was prepared by the use of a small gyratory crusher which reduced the material down to one-half inch maximum size and this product was then passed through a grinder which reduced it still further in size. This reduced product was then screened into various fractions by means of a small Hummer vibrating screen. Mechanical analyses were made of these fractions and finally they were combined in the required amounts to make up enough material for use in concrete specimens.

## Gradations of Stone Sands Used

The gradations of the stone sands thus prepared are shown in Table I and are likewise shown on the triaxial diagram in Fig. 1. Table I also shows the unit weight and the percentage of voids of sands in these various gradations.

The coarse aggregate was graded as follows:

	Per cent
Total retained on 2 inch square opening	0
Total retained on 1½ inch square opening	27
Total retained on 1 inch square opening	55
Total retained on ½ inch square opening	83
Total retained on No. 4 square opening	100

The percentage of voids in this material was 44.7 by dry, loose volume and 39.3 by dry, rodded volume.

## Design of Concrete Mixtures

The workability of concrete is governed not only by the characteristics and the gradation of the fine aggregate, but also by the characteristics of the coarse aggregate and by the concrete proportions used. Furthermore, the percentage of fine particles including the cement has great influence on the workability of concrete. The problem of determining the best gradation

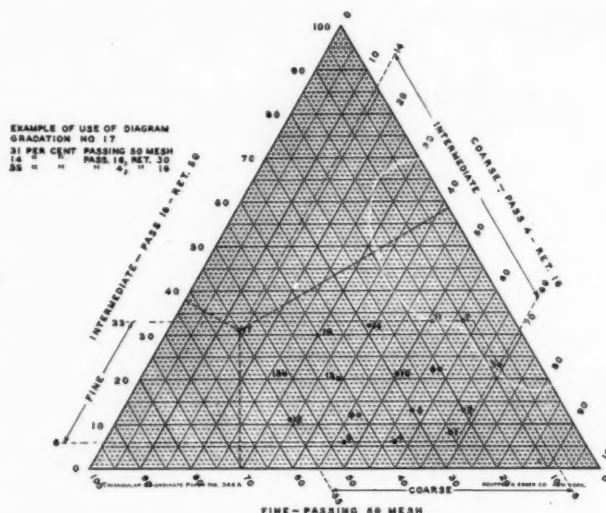


Fig. 1. Gradation Chart.

for stone sand is, therefore, not a simple one and to solve it completely a large amount of testing would be required, more than was felt should be devoted to this particular problem at present in view of a number of other important problems needing investigation.

It was decided to make use of the mortar-voids method for proportioning the concrete. Mortar-voids tests were made on the stone sands of various gradations and as a result of these preliminary tests, concretes were designed to have approximately the same modulus of rupture and the same consistency as measured by the slump test. Naturally, to accomplish this end, a wide range in cement content had to be used.

TABLE I  
GRADATION AND OTHER CHARACTERISTICS  
OF  
STONE SAND USED IN TESTS

No.	Gradation of Stone Sand					Stone Sand Fineness Modulus	Percent Dust Passing #200	Unit Weight, lbs.		Per Cent Voids	
	Total per cent retained on							Loose	Rodded	Loose	Rodded
	8	16	30	50	100						
1	6	25	54	92	99	2.76	0.6	90.1	98.5	47.9	43.1
2	5	20	48	87	97	2.57	1.8	91.9	100.2	46.9	42.0
3	1	8	31	77	95	2.12	3.1	89.0	99.0	48.6	42.8
4	10	37	75	94	99	3.20	0.6	92.6	100.8	46.5	41.8
5	8	30	60	87	97	2.82	1.8	94.6	103.6	45.3	40.2
6	4	20	42	78	95	2.39	3.1	92.2	102.7	46.7	40.7
7	1	10	28	67	94	2.00	3.7	90.0	102.0	48.0	41.1
8	13	47	74	94	99	3.27	0.6	95.0	102.9	45.2	40.6
9	11	41	66	88	97	3.03	1.8	97.0	105.3	44.0	39.1
10	7	29	54	79	95	2.64	3.1	97.4	106.6	43.8	38.4
11	4	16	40	67	93	2.20	4.3	96.0	104.7	44.6	39.5
12	19	55	73	89	97	3.33	1.8	99.7	108.8	42.4	37.1
13	13	41	65	80	95	2.94	3.1	100.9	109.8	41.7	36.6
14	9	29	47	68	93	2.46	4.3	99.1	109.6	42.7	36.7
15	18	51	66	79	94	3.08	3.7	103.0	112.5	40.5	35.0
16	13	40	56	70	93	2.72	4.3	101.7	111.0	41.3	35.8
17	21	55	60	69	94	2.99	3.7	104.3	114.2	39.7	33.9

The concrete specimens were tested at the age of 14 days. Their proportions are as shown in Table II and in this table are also shown the values for compressive strength and modulus of rupture, the average of two tests in each case; likewise the cement contents are given.

It will be noted in Table II that the concrete proportions were so arranged that there was an excess of mortar, for it was desired that the coarse aggregate

have as little influence on the workability as possible in view of the fact that the study was made to determine the effect of the fine aggregate on workability. As each mixture was made, the operators studied it carefully and they used their judgment as to what constituted good, poor or other grades of workability. Each mixture was graded in workability in accordance with the ease with which it could be placed in the forms and finished, and its behavior in the slump and

TABLE II  
DATA ON CONCRETE  
PAVEMENT MIXES HAVING APPROXIMATELY CONSTANT STRENGTH  
MADE WITH 17 GRADATIONS OF STONE SAND

No.	Slump (ins.)	Flow	Workability	W/C	Bags cement per Cu. Yd.	Strength (14 days)		$\frac{b}{b_0}$	Proportions (Loose Volume)			Proportions (Rodded Volume)		
						Modulus Rupture lbs./sq. in.	Compres- sion lbs./sq. in.		Cement	F. A.	C. A.	Cement	F. A.	C. A.
1	1- $\frac{1}{4}$	160	2	.81	6.06	776	3940	.74	1	2.5	3.6	1	2.3	3.3
2	2- $\frac{1}{2}$	172	1	.74	6.97	882	4520	.76	1	2.0	3.3	1	1.8	3.0
3	2	159	1	.69	7.34	945	4580	.77	1	1.8	3.1	1	1.6	2.8
4	1- $\frac{3}{4}$	159	2	.74	6.13	828	4470	.76	1	2.4	3.7	1	2.2	3.3
5	2	160	2	.72	6.37	958	4350	.76	1	2.3	3.6	1	2.1	3.2
6	2	174	1	.71	6.92	975	4760	.76	1	2.0	3.3	1	1.8	3.0
7	3- $\frac{1}{2}$	181	1	.73	7.18	772	4660	.76	1	1.9	3.2	1	1.7	2.9
8	1- $\frac{1}{4}$	159	4	.76	6.00	913	4280	.76	1	2.6	3.8	1	2.4	3.4
9	1- $\frac{3}{4}$	172	3	.72	6.37	864	4380	.77	1	2.3	3.6	1	2.1	3.3
10	1- $\frac{3}{4}$	150	3	.76	6.16	784	4070	.76	1	3.4	3.6	1	2.2	3.3
11	2- $\frac{1}{2}$	162	1	.72	6.91	842	4580	.77	1	2.0	3.3	1	1.8	3.0
12	$\frac{1}{2}$	144	5	.77	5.66	893	3890	.76	1	2.0	4.0	1	1.7	3.6
13	2	150	3	.77	5.95	894	4150	.76	1	2.5	3.8	1	2.3	3.4
14	1- $\frac{1}{2}$	145	2	.75	6.38	884	4300	.76	1	2.2	3.6	1	2.0	3.2
15	1- $\frac{1}{2}$	158	2	.76	5.87	888	4360	.76	1	2.5	3.8	1	2.3	3.5
16	2- $\frac{1}{4}$	158	1	.76	6.21	889	4650	.76	1	2.3	3.7	1	2.1	3.3
17	2- $\frac{1}{4}$	162	2	.78	5.93	869	4720	.76	1	2.4	3.8	1	2.2	3.5

Notes: Workability numbers indicate: 1—Excellent; 2—Very Good; 3—Good; 4—Fair; 5—Poor.

W/C—Water cement ratio, i.e. ratio of volume of water to volume of cement used in the mixture.

b is the solid volume of coarse aggregate per unit volume of concrete.

b<sub>0</sub> is the solid volume of coarse aggregate per unit volume of coarse aggregate measured dry and loose.

F. A. means "fine aggregate."

C. A. means "coarse aggregate."

flow table tests was also taken into consideration. As each mixture was completed it was given a workability number which indicated the degree of workability of that particular mixture. Five degrees of workability were distinguished as the result of the joint opinion of two of the operators. No. 1 was "excellent"; No. 2,

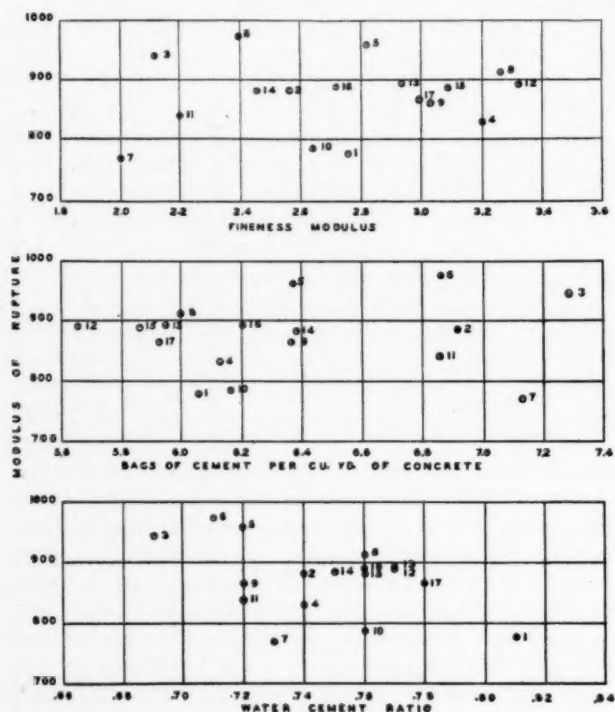


Fig. 2. Relation Between Modulus of Rupture and Fineness Modulus, Bags of Cement per Cubic Yard of Concrete, and Water Cement Ratio.

"very good"; No. 3, "good"; No. 4, "fair" and No. 5, "poor." As a matter of fact, No. 4 and No. 5 might be considered as unworkable mixtures under certain circumstances.

Although the mixtures were designed for constant strength, the actual strength results obtained are only reasonably constant, although they are as good as might be expected considering the fact that they represent the results of only two tests. Had we been able to make more beams and compression specimens, greater uniformity in the strengths of these various mixtures would have been obtained.

The test results are shown in Fig. 2, plotted against the fineness modulus of the stone sand, the bags of cement required per cu. yd. of concrete and the water-cement ratio.

Table II contains the results of mixtures having a comparatively large amount of cement per cu. yd., such as would be used in pavement mixtures. In Table III are shown the results of an additional series of concrete tests in which the cement content was decreased and the mixtures are more nearly those which would be used in concrete bases for pavements. These results

are plotted in Fig. 3. The curves in both Figs. 2 and 3 are not particularly significant except that, considering the small number of specimens used, they indicate reasonable uniformity in modulus of rupture for the variations in fineness of sand, cement content and water-cement ratio used in the tests. Depending upon the fineness of the sand, a wide range in cement content must be used to obtain the same strength and, furthermore, a wide range in amount of water must be used in mixing the concrete to obtain the same consistency with various gradations of sand.

In Fig. 4 these same results are plotted with the cement content in bags per cu. yd. of concrete as the ordinates and the fineness moduli of the sands as the abscissas. By fineness modulus is meant the summation divided by 100 of the total percentages of sand retained on the Nos. 4, 8, 16, 30, 50 and No. 100 sieves. It is a figure which is a measure of the fineness of the sand. By no means is it a perfect measure but, nevertheless, it is useful in expressing the fineness, as nearly as it can be expressed by a single number. A small fineness modulus indicates a fine sand and a large fineness modulus, a coarse sand. Most concrete sands range from approximately 2.5 to 3.5 in fineness modulus value.

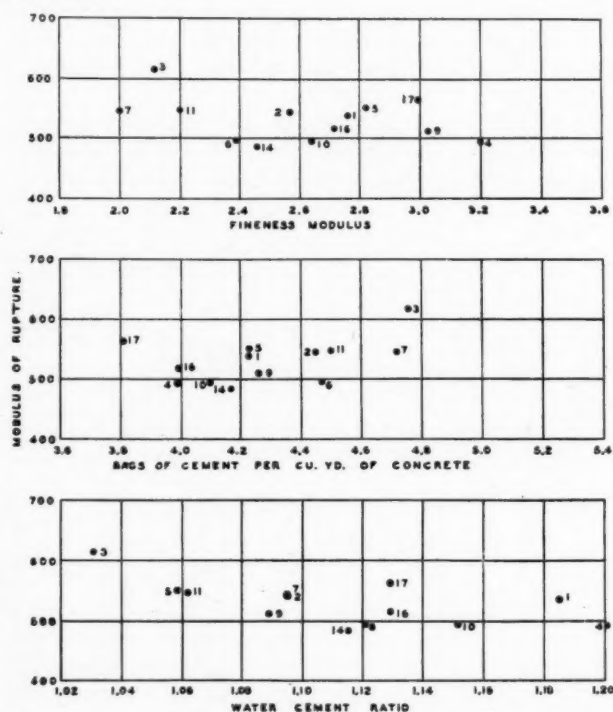
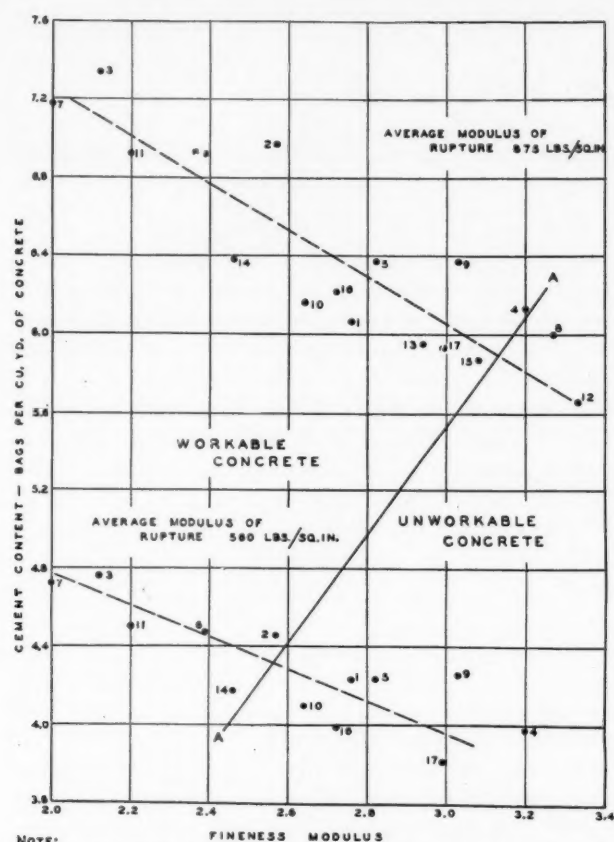


Fig. 3. Relation Between Modulus of Rupture and Fineness Modulus, Bags of Cement per Cubic Yard of Concrete, and Water Cement Ratio.

Fig. 4 is a very interesting figure for it shows, in the first place, that the finer the sand, the greater is the cement content required to produce concrete of a required strength. This is so with both the rich mixes and the lean mixes. The desirability of maintaining



NOTE:  
A-A IS THE DIVIDING LINE BETWEEN WORKABLE AND UNWORKABLE CONCRETE

Fig. 4. Relation Between Cement Content and Fineness Modulus.

a constant sand gradation is also clearly evident. The line "A-A" has been drawn to separate the workable

concrete from the unworkable concrete, as determined by our judgment in these tests. It will be noted that when concrete mixtures are to be made with a small amount of cement, if workable concrete is required a relatively fine sand should be used. On the other hand, for rich mixtures, such as are used in concrete pavements, it is quite feasible, desirable and economical to use a much coarser grade of sand. For illustration, for a 6-bag batch of concrete it seems to be feasible to use sand whose fineness modulus is approximately 3.0. A sand much coarser than this would result in unworkable concrete. If the sand is made finer it will be noted that the cement content must be increased in order that the strength may remain the same. For a lean mix, one containing  $4\frac{1}{2}$  bags of cement per cu. yd., a fineness modulus up to 2.6 or 2.7 should be used and a coarser sand than this might result in an unworkable concrete. It would seem desirable to use as coarse a sand as possible so as to obtain high concrete strength and the limit to coarseness is controlled by the desired degree of workability of the concrete.

There are a number of gradations of sand which will satisfy the requirement of a given fineness modulus. But it would seem that sands having the following gradations should be desirable from the standpoint of their economy in the production of high strength concrete having good workability.

It may prove easier and more economical, however, to produce sands of other gradations than those given. For illustration, the amount of material passing the No. 50 sieve may be decreased and likewise the maximum size may be made not larger than the No. 8 sieve opening. The most economical gradation will de-

(Continued on page 27)

TABLE III  
DATA ON CONCRETE  
PAVEMENT BASE MIXES HAVING APPROXIMATELY CONSTANT STRENGTH  
MADE WITH 17 GRADATIONS OF STONE SAND

No.	Slump (ins.)	Flow	Workability	W/C	Bags cement per Cu. Yd.	Strength (14 days)		$\frac{b}{b_0}$	Proportions (Loose Volume)			Proportions (Rodded Volume)		
						Modulus Rupture lbs./sq. in.	Compression lbs./sq. in.		Cement	F. A.	C. A.	Cement	F. A.	C. A.
1	1- $\frac{1}{2}$	178	4-5	1.18	4.23	536	1840	.75	1	3.6	4.8	1	3.3	4.3
2	1	176	3	1.10	4.45	544	2130	.76	1	3.2	4.6	1	3.0	4.2
3	1- $\frac{1}{2}$	179	2-3	1.03	4.76	616	2480	.77	1	3.0	4.4	1	2.7	4.0
4	$\frac{1}{2}$	179	5	1.21	3.98	492	1450	.74	1	3.8	5.0	1	3.5	4.5
5	$\frac{1}{2}$	184	4-5	1.06	4.23	550	2240	.76	1	3.5	4.9	1	3.2	4.4
6	2	200	1-2	1.12	4.47	496	2100	.76	1	3.2	4.6	1	2.9	4.2
7	1- $\frac{1}{2}$	190	1	1.10	4.72	545	2150	.77	1	3.0	4.4	1	2.7	4.0
9	$\frac{3}{4}$	183	5	1.09	4.26	511	1960	.76	1	3.4	4.8	1	3.2	4.4
10	1- $\frac{1}{4}$	168	3-4	1.15	4.10	496	1870	.75	1	3.6	4.9	1	3.2	4.5
11	1- $\frac{3}{4}$	191	1-2	1.06	4.50	548	2320	.77	1	3.1	4.6	1	2.9	4.2
14	1	165	2-3	1.12	4.17	484	2110	.77	1	3.5	5.0	1	3.1	4.5
16	1- $\frac{1}{4}$	169	4-5	1.13	3.99	518	2350	.77	1	3.7	5.2	1	3.4	4.7
17	1- $\frac{1}{2}$	170	3-4	1.13	3.81	562	2140	.76	1	3.9	5.4	1	3.5	4.9

Notes: Workability numbers indicate: 1—Excellent; 2—Very Good; 3—Good; 4—Fair; 5—Poor.

W/C—Water cement ratio, i.e. ratio of volume of water to volume of cement used in the mixture.

b is the solid volume of coarse aggregate per unit volume of concrete.

$b_0$  is the solid volume of coarse aggregate per unit volume of coarse aggregate measured dry and loose.

F. A. means "fine aggregate."

C. A. means "coarse aggregate."

## EDITORIAL

### Effective Research

A NECESSARY characteristic of concrete for building and highway construction is durability or permanence. In order that concrete may be durable, engineers have recognized the extreme necessity of insuring that the materials which are to enter such construction shall be sound. To guarantee the use in concrete construction of only those materials which were unquestionably sound, rigid specifications were established and the necessity for obtaining definite information within a limited length of time led to the development of so-called accelerated soundness tests. Notable among these was the sodium sulphate test.

When durability first became a matter of concern to engineers, it seems, for reasons which evade explanation that unsoundness was almost invariably attributed to the aggregate used in the concrete, and this quite naturally led to the application of rather severe tests for determining the soundness or durability of such aggregate.

It was early recognized by the Association's Bureau of Engineering that a serious injustice might be done crushed stone if such an opinion continued to prevail and consequently it was felt that preliminary investigations might properly be conducted in the research laboratory, looking towards the obtaining of more definite information on this important matter. It is interesting to note that as a result of the preliminary investigations, reported in the July, 1929, issue of *The Crushed Stone Journal*, it was stated, "the sodium sulphate test may reject material which has been shown to be entirely sound, not only in practice but as proven by a severe form of freezing and thawing test," and "the action of the sodium sulphate test on Portland cement mortar does not seem to be as severe as the action of the freezing and thawing test." These preliminary investigations brought to light the very interesting question as to whether failure because of the use of unsound materials might not be attributed to unsoundness in the mortar as well as to the generally accepted conclusion that unsoundness existed in the aggregate only. As a result of these preliminary indications a much more detailed and comprehensive investigation was inaugurated in our research laboratory with results which are well known to the industry, and which in no uncertain terms substantiated the previous belief that concrete failure might well be attributed to

unsoundness in any of the materials used in making the concrete. It also became more definitely evident that the sodium sulphate test is distinctly unreliable and might easily cause the condemnation of aggregates which would prove entirely satisfactory in service.

Undoubtedly the investigations conducted by our Bureau of Engineering on soundness assisted in directing the attention of engineers to the need of further investigations. A number of tests have been conducted by other investigators and it is interesting and gratifying to note that in general the conclusions are in agreement with those determined upon in our own laboratory. The latest addition to this constantly growing list is the United States Bureau of Public Roads, whose investigators, F. H. Jackson and George Werner, report in the April issue of *Public Roads* the following significant conclusions:

"1. That within the range in variation of aggregate quality covered by these tests, variations in the quality of mortar caused by changes in the water-cement ratio of the cement paste will have a greater effect upon the resistance of concrete to frost action than will variations in the type and character of the coarse aggregate.

"2. That failure of coarse aggregates in the sodium sulphate soundness test is not necessarily an indication that the aggregate is unsatisfactory for use in concrete to be exposed to the weather."

Although there are still some who unfortunately seem inclined to continue to arbitrarily condemn crushed stone because of its failure in the sodium sulphate soundness test, disregarding other considerations, it nevertheless seems destined that a much more liberal interpretation of this test will prevail in the future, which should be distinctly advantageous to the crushed stone industry and save it thousands of dollars.

The organized, cooperative effort of the crushed stone industry, as expressed in the National Crushed Stone Association, has made possible this effective service to the industry. The Association's research laboratory is constantly engaged in investigating problems of equal and greater importance to the industry, and none will deny the urgent necessity of continuing this highly necessary activity. The continued and generous support of the entire industry must be forthcoming if such is to be the case.

## Protect Your Business

**I**NSURANCE, whether it be personal or business, is commonly recognized as a safeguard against adversity. In a small group which was recently discussing the business situation this highly significant remark was made, "Well, I certainly hope things won't get so bad that I'll have to give up any of my insurance," and it seems to us that this opinion must be held by most business executives today. "Balance the budget" has become a popular slogan of the day and confronted with decreasing incomes we have all found it necessary to undertake this disagreeable task. Yet we venture the statement that with very rare exception curtailments have not been made in the funds set aside for insurance.

Insurance is a definite and positive form of protection. Falling into a similar category are the activities of the National Crushed Stone Association: The work of our Bureau of Engineering—personal advice given in answer to specific problems, contacts with state highway departments in connection with the formulation of specifications covering the use of our material, and highly important research investigations conducted in the Association's research laboratory; the ability of the Association to express the opinion of the industry in matters involving legislation; and many additional phases of our work too numerous to mention. Such activities very definitely protect the present and future business operations of the members of the Association. Is it unreasonable, therefore, to draw the parallel that membership dues in the Association are in the nature of premiums paid for a continuance of business success?

And yet when curtailments in operating expenditures are made, too frequently "association dues" are classified as "unnecessary overhead" and are either drastically reduced or in some instances entirely eliminated. The money you spend in association dues, if you will but recognize it, is a "most necessary item in your actual operating expense. It should be definitely set up in the budget at the beginning of each operating year and not cut down or actually eliminated at the first signs of economic distress.

We have yet to reach that happy state of affairs when we can point to lessons learned from the recent depression and yet even at this date the depression has served to effectively demonstrate that man was not made to live alone. To be successful he needs help in everything he undertakes and the measure of his success lies in the extent to which he believes in efficient organization. He must support his industry or his industry will not support his business.

By permitting your premiums to lapse you are jeopardizing your future business success. If you have not already done so, you should immediately forward check for your current dues to the Washington office.

## Needed Road Work Offers Unemployment Solution

**T**HAT public work, such as road building, is one of the best ways for the country to furnish employment is shown in the actual employment figures in 1931," declared W. C. Markham, Executive Secretary of the American Association of State Highway Officials, here recently.

"An average of approximately 290,000 men had road jobs on Federal Aid and state projects during 1931," Mr. Markham asserted. "It is conceded by those who have studied the subject that for every man working directly on the roads there is employment given two men who are preparing or transporting materials. On that basis the Federal Aid and state work alone was responsible for the employment of an average of 870,000 men throughout 1931. Local road work and street building brings the total number of men employed, directly and indirectly, in the improvement of automobile facilities to well over two million workers.

"To furnish work it is not necessary to avoid the use of machinery," Mr. Markham went on. "While it is true that the highest proportion of manual labor is found in hand-labor projects, such as working in virgin soil or spreading sand or gravel over an earth bed, it is also true that about nine-tenths of the road money spent for high type pavements also goes to labor. This is so because no intrinsically valuable materials go into roads; the hand of labor plays the major part in preparing these materials, in building equipment and in transporting these supplies to the project.

"The Federal government, the state and the local community can feel that when it makes a dollar available to road construction that it will be a dollar well spent, a dollar invested mostly in labor. Of great import, also, is the fact that this country needs many thousand more miles of good highways, highways that will cut down car operating costs to the individual and road upkeep costs to government. The public is now paying a tremendous tribute to these two items which can only be reduced by building adequate road surfaces.

"The prevailing low construction prices, the economic need for improved highways and the all important call for more jobs make this a time when every community should devote every cent possible to roads," concluded Mr. Markham.

---

### BRUCE BARTON SAYS:

*"You can't advertise today and quit tomorrow. You're not talking to a mass-meeting. You're talking to a parade."*

# National Safety Council Announces New Service

ON the sound and praiseworthy theory that every industrial concern is entitled to the benefits of organized accident prevention the National Safety Council has just announced a practical plan for spreading the gospel of Industrial Safety throughout the length and breadth of the land.

Every company, large or small, regardless of whether it holds membership in the Council, can have that organization's help in establishing a definite working plan for a continuous campaign of accident prevention.

The safety work of several thousand industrial members in all industries has recently been analyzed and their most effective technique will be made available to any plant desiring a specific course of safety procedure without cost. The sole obligation on the part of the employer will be to provide a few essential facts from which Council engineers can draw up a practical working plan commensurate with the needs of the company and applied to the specific operating problems.

Also as a result of this survey a new service is offered by the Council to old and prospective new members. It is known as the "Complete Industrial" Service and is exactly what its name implies—adequate, sufficient, all-inclusive. It represents a high standard in safety technique and reaches not only management, key safety men and foremen but also every employee.

Born of experience, it is authoritative which means it isn't so much a question of trying it as of using it. It reflects another decidedly progressive step in the work of the Council for it is a definite, tested method of reducing accidents.

A description of the new service may be pretty well summarized in one word, "personalized." In the past, warfare on accidents has been directed mainly by foremen and safety engineers. The new plan takes cognizance of the fact that it is really everybody's business. Every person connected with the plant becomes a sort of stockholder in the work. His interest is awakened and sustained through a twelve-month schedule of safety contacts.

For example, inter-department or inter-group safety contests have played an important part among companies conducting the most successful safety programs. Through this new service the Council provides its new Industrial Safety Trophy, an attractive heavy bronze plaque 7½ x 11½ inches, to be awarded the department or group winning the year-round safety contest within the company. The trophies are provided for display throughout the year and at the conclusion of

**Industrial Safety Trophy  
Awarded by the National  
Safety Council in Department or Group Safety  
Contests.**



the contest are inscribed and presented with proper ceremony to the winning group. In this way every employee has a definite, intimate part to play. A new trophy is provided annually.

Another paramount feature of the new plan is its reaching the individual workman. The popular little magazine, *The Safe Worker*, is sent out monthly to every employee in the company. Payroll messages also are provided to be given on pay day to every worker as an added reminder for safety. In many other ways management reaches the man on the job who, after all, must be won over to accident prevention if the program is to be successful.

The National Safety Council will gladly furnish full information on the new complete membership, and also stands ready to help any reader of *The Crushed Stone Journal* in laying out a practical working plan for handling its accident problems, without any membership obligation whatsoever.

The Council stands ready not only to help broadcast these remarkable achievements in human conservation but also is anxious to help any and all industrial concerns to get their safety work started off on the right foot.

## H. M. Davison Leaves Harnischfeger Sales Corporation

H. M. Davison, who has been Excavator Sales Manager of the Harnischfeger Sales Corporation, Milwaukee, has left that organization. Mr. Davison is now in the East and is completing some plans in connection with a new organization, information concerning which will be issued shortly.

## An Investigation of the Gradation of Stone Sand for Concrete

(Continued from page 23)

### SUGGESTED GRADATIONS OF STONE SAND, DEPENDING ON CEMENT CONTENT

		Approximate Number of Bags of Cement per Cu. Yd.	
		4.5	6.0 or over
Total Per cent Passing		Total Per cent Passing	Total Per cent Passing
Passing No. 4	4	100	100
" No. 8	8	85	80
" No. 16	16	70	60
" No. 30	30	52	40
" No. 50	50	27	20
" No. 100	100	5	3

Fineness modulus = 2.6

3.0

Note: A number of other gradations would be suitable also.

pend to a considerable extent on the gradation of the parent product. It is suggested, however, that the amount passing the No. 100 sieve be kept within the above suggested limits and that the values for fineness modulus be made to approximate those given in Figure 4. Note that these vary with the cement content of the concrete.

The present tests are meager and they omit consideration of a number of variables which control the workability of concrete, but if all the variables were taken into account, an exceedingly large concrete investigation would have to be undertaken involving great expense. However, it is felt that the present investigation has given the prospective producer of stone sand some useful, even if only approximate, information as to the gradation of sand which he should produce.

## Gas Tax Money for Roads Only, Say Originators

The misuse of gasoline tax money for purposes other than road building has provoked a nationwide storm of protest not only from the public but from those who were original sponsors of the plan to make highways pay for themselves.

C. C. Chapman of Oregon, who helped Oregon establish the country's first gasoline tax, recently declared: "In relieving property of many millions of dollars in taxes for highways, and assuming the highway burden themselves, motor vehicle owners feel that the integrity of motor vehicle and gasoline taxes should be protected from diversion into general government channels which should be financed by general taxes.

"Attempts to divert gasoline tax money will sacrifice the confidence and support of motor vehicle owners. No state can afford to risk provoking motorists into withdrawing the huge financial support they now give highways. Attempts to raid gasoline tax funds for other purposes will provoke antagonism; if successful, revenues will be wrecked and additional burdens will be thrown on property.

"The original theory of the sponsors of the gasoline tax was that road users should pay for roads in proportion to their use. Motorists supported the tax, and increases in the tax, with the assurance that the money would be used only for road purposes. Diversion is a violation of the motorists' faith."

White L. Moss, former state senator of Kentucky, says: "As one of the originators of the gasoline tax my sole purpose in proposing a bill for a gasoline tax was to cause the owners and users of automobiles to pay for the construction and maintenance of state highways in proportion to their use of these roads. I consider this tax merely a road toll. I can see no just or reasonable argument for diverting any part of the gasoline tax for any purpose whatsoever."

That the gasoline tax must not become confused with ordinary taxes is pointed out by Horatio S. Earle, the first State Highway Commissioner of Michigan:

"The so-called gasoline tax is not a tax, but simply a toll, just as much as was the old toll paid to corporations that built and maintained the toll roads. The gasoline tax is paid by owners and users of automobiles to build and maintain roads, to be used for business and pleasure by them. Any of the money that is taken and used for any other purpose is robbery."

"Judge," said the Contractor to his Lawyer, "Doctor says I got about a month to live; I want to make my will."

"Fix it so my overdraft in the First National Bank goes to my wife—she can explain it to them."

"My equity in my automobile I want to go to my son. He will have to go to work then to meet the payments."

"Give my unpaid bills to the Bonding Company; they took some awful chances on me and are entitled to something."

"That new-fangled machine on the job I want the Resident Engineer to have. He made me buy it; maybe he can make it work."

"My retained percentage give to the State; I never expected to get it anyway."

"My equipment give to the junk man. He has had his eye on it for several years."

"My keg I want to go to the bootlegger. I hope it costs him as much to keep it wet as it has me."

"I want you to handle the funeral for me, Judge. Any undertaker will do, but I want these six material men for pallbearers. They have carried me so long they might as well finish the job."—*Exchange*.

A nice looking young lady found herself stranded in Durango the other night, says the *Durango News*. She asked the constable to tell her of a place for a night's lodging and he said he did not know of any place unless she slept with the station agent. "Sir," she said, "I'll have you understand I'm a lady." "So's the station agent," the constable replied.—*Exchange*.

## Hardinge Conical Scrubber

The Hardinge Conical Scrubber is a large conical drum rotated on trunnion bearings. Feed enters at one end and is discharged at the other end into a revolving trommel screen. Only sufficient water to coat the material is introduced at the feed end.

As the drum revolves, the material within the scrubber is thoroughly mixed. The weight of the mass and the rubbing action of the material against itself, loosens the dirt and when the stone and gravel is discharged into the screen under a small stream of water, the manufacturers claims it is rinsed absolutely clean of all clay and silt.

The Scrubber is built in 7 standard sizes, with a capacity range of 8 to 600 tons an hour. Repairs, it is said, are practically nil, as there are no internal moving parts, no submerged bearings and no packing glands to maintain. Power costs are low and practically no operating attention is required.

These Scrubbers have been used for years to clean phosphate pebble, one of the most difficult of materials to wash. According to the manufacturers, not only was the product improved when the change in operation was made, but a very considerable reduction in production costs was obtained.

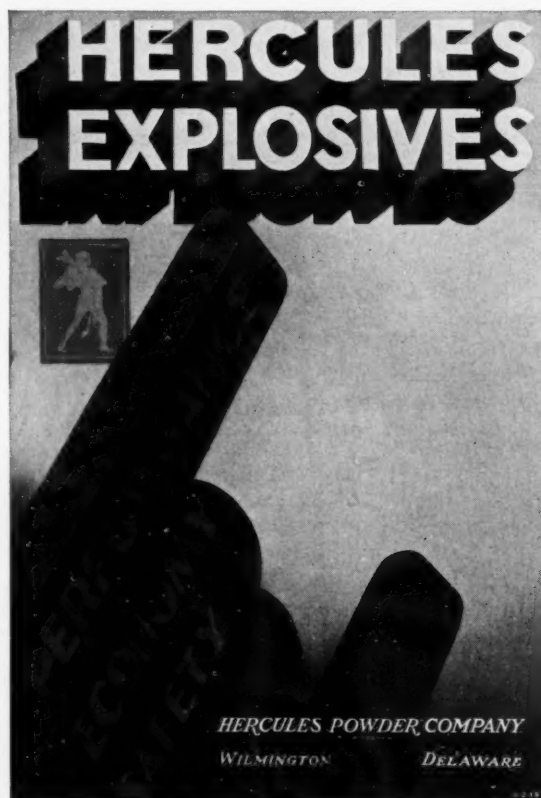
## Allis-Chalmers Issues Bulletin on Washing Equipment

The Allis-Chalmers Manufacturing Co. of Milwaukee, Wisconsin, has recently issued Bulletin 1471 in which are described in considerable detail various types of washing equipment. Separate sections in the bulletin are devoted to the following classes of equipment: Scrubbers, Log Washers, Sand Washers, Scrubber Screens, Vibrating Screens. The bulletin is put up in attractive form and is well illustrated. Copies will be gladly furnished upon request direct to the Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

### THE WORM TURNS

When the clock struck the midnight hour, father came to the head of the stairs and in a rather loud tone of voice said: "Young man, is your self-starter out of order tonight?"

"It doesn't matter," retorted the young man, "as long as there's a crank in the house."—*Exchange*.



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## FOR SALE

Here is an opportunity to buy one of the most valuable limestone deposits in the Eastern part of the United States at a bargain. Owner must sell and is willing to take 50 per cent of the purchase price in cash and, if purchaser desires, will leave 50 per cent of the purchase price in plant.

Forty-one acres limestone land, with high analysis, large quarry developed, practically no over burden and no water to pump. All buildings and machinery in first class condition.

Sufficient machinery to manufacture 10,000 tons of agricultural lime per year, and to crush 100,000 tons of crushed stone for road construction. Complete concrete block and

tile plant equipped to make two million concrete blocks and tile per year, as well as concrete silo staves, concrete burial vaults, and fancy concrete pottery.

Large tube mill to grind raw stone into limestone flour, capacity 25,000 tons per year.

Farm land in connection with quarry, in high state of cultivation, dwelling and farm buildings in first class condition, with all city conveniences.

This plant has a well established trade, and has shown a large profit every year, 1931 being a banner year. Sufficient orders booked for 1932 to show a good profit.

Write for full particulars.

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# **This G-E Capacitor**

## **Is Saving Enough Power**

### **To Pay for Itself in Two Years**

**H**ERE is a 90-kv-a. capacitor installation at the Virginian Limestone Corporation, Ripplemead, Va. Mr. C. D. Klotz, Vice President and General Manager, says: "This capacitor has proven most reliable in service, having required no attention since its installation. It has not only improved our line voltage but in comparing our power costs of last year with those during the same operating period of the previous year we find:

#### **Before Modernization**

**Kv-a. Demand . . . . . 825**

#### **After Modernization**

**Kv-a. Demand . . . . . 775**



or a saving of \$950.00 in power costs alone. This saving is practically 50 per cent on the initial investment and will pay for the capacitor within two years."

Investigate your power-factor situation to-day. General Electric power-factor corrective equipment — capacitors, synchronous condensers, synchronous motors — will effect economy and improve plant operation. Look into these savings as a part of your 1932 modernization program. Simply write or call your nearest G-E office for the most practical solution of your power-factor problem.

***Modernization Reduces Costs - - - Increases Profit***

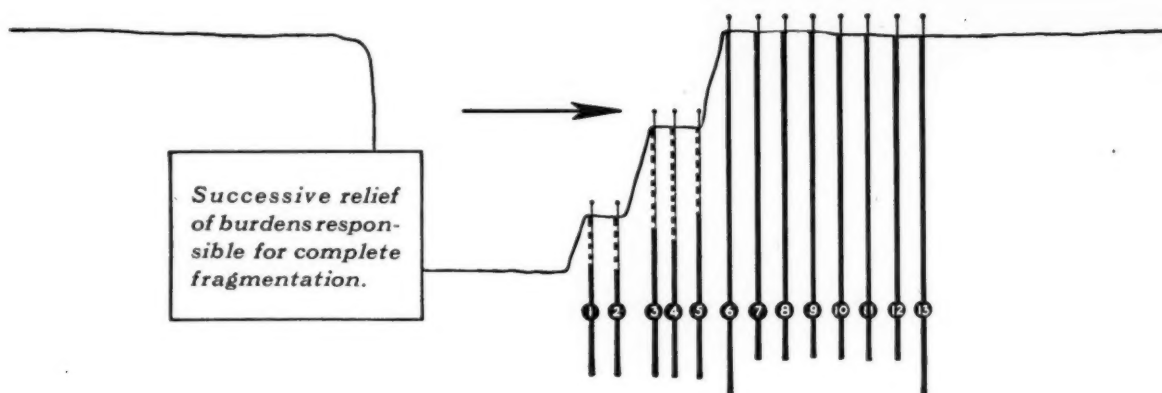
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**Y**OU doubtless have seen the statistics: an area 4,400 ft. long by 200 ft. wide, containing over 4,000 6-in. holes with a total footage depth of over 125,000 ft., 440,966 lbs. of explosives and 199,273 ft. (about 38 miles) of Cordeau-Bickford Detonating Fuse. These are record-breaking figures: they represent a winter's work consummated in one gigantic blast—the largest in history.

But back of this size is sound common sense, sound engineering, and a new proof of the value of Cordeau-Bickford. For the object of this blast was not mere displacement, but *fragmentation*; and

to get this result it was essential that the load should go in successive stages. To the camera eye it appeared as one huge instantaneous blast and only one electric cap was used; but the Cordeau hook-up was so planned that successive holes and successive rows of holes fired in a distinct rotation to permit relief of burden by stages.

Thus it was that the shock did not result in violent earth tremors, for the force of the explosive was expended in displacing *and fracturing* the stone. Not only was the blast an outstanding one for size, but — and this is most important — it was thoroughly efficient.

Cordeau-Bickford has made the modern giant blast possible — *and practicable*. The Ensign-Bickford Company, Simsbury, Connecticut.

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Close-up view after the blast. Notice the complete fragmentation — ready for the shovels.

